CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
Karen Ross, Secretary

2015
Specialty Crop Block Grant Program – Farm Bill (SCBGP-FB)
FINAL REPORT

USDA, AMS Agreement No:
Specialty Crop Agreement No. 15-SCBGP-CA-0046

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CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 1	**Project Title:** California's Agriculture Rock Stars	
Grant Recipient: Buy California Marketing Agreement	**Grant Agreement No.:** SCB15001	**Date Submitted:** December 2018
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Project Summary

The initial purpose of the project was to provide a unique opportunity for specialty crop producers and representative organizations to leverage a partnership between Buy California Marketing Agreement (BCMA) and Visit California that produced a national media campaign designed to promote California specialty crops across a diverse set of digital channels. This project fulfilled a need for a promotional umbrella to help tie in the independent promotional messages of 25 plus specialty crop marketing organizations and 350 specialty crops producers and produce statewide marketing for all California specialty crops. The campaign content and activities were designed to change consumer behavior by creating a greater awareness and affinity for California specialty crops and in turn positively affect the sales of California specialty crops.

Consumer desire was higher than ever for knowing the origin and way their food is produced. The consumer's interest in being acquainted with those that produce their food was also at its highest point ever. The number of diverse outlets being developed through which consumers could interact with and get to know their local specialty crops and producers without a doubt fueled this growing interest to "get closer to their food." The number of experiences, some dubbed "agritourism"; increasing in popularity in communities statewide (i.e. farmers markets; locally sourcing restaurants; specialty crop centric festivals; locally sourcing retailers; farm stands; U-pick; community gardens; the rise in specialty small and new farms producing niche specialty crop items; a trend in food culture to eat seasonal and local and support local farmers) all made such a promotion timely to execute to build a strong statewide and national message about the opportunities to enjoy locally grown California specialty crops and support producers.

This project built upon two previous grant funded media campaigns, 2013 Specialty Crop Block Grant Program (SCBGP) Project 1 *California, Always in Season* and 2014 SCBGP Project 1 *California, Always in Season – Building Community*. Both projects achieved significant gains in consumer awareness and affinity for California specialty crops through content that targeted a national audience and promoted the diversity, seasonality and local nature of the various food and agritourism experiences that were available throughout the state to enjoy California specialty crops. This project's media campaign and activities built upon the gains in awareness by consumers for California specialty crops and grew the audience of California consumers engaging with California agriculture and purchasing California specialty crops. The project continued successful elements and applied learnings from each of the previous projects making refinements to increase the impact of the project on the target consumer audience (i.e. continued and increased investment in video content; continued investment in consumer events; continued social media content development; increased investment in key social media platforms growing in popularity e.g. Instagram; adoption of a 100 percent digital campaign for both efficiency of media spends and higher quality performance metrics; investment in retail promotions to impact sales of California specialty crops).

Project Approach

Campaign Finalization, Media Campaign Stakeholder Engagement, Media Purchase, Content Development: Campaign finalization was completed on April 1, 2016 as contractor submitted their complete media recommendation and creative concepts. The media recommendation included the program objectives to deepen the relationship with consumers using unique social tones and voices and to increase awareness of and preference for California-grown specialty crops. The media recommendation outlined a target audience of people with culinary and travel interests and a plan to deliver the program message through video; digital and social media content. Also included in the campaign was an extension to have a presence at two high profile consumer events, Los Angeles Food and Wine and the Eat Real Festival.

The campaign was shifted from a print and digital campaign to a full digital campaign and the California's Agricultural Rockstar – Farm2Fan content was featured on the following Time Inc. platforms/properties: Food and Wine; Cooking Light; Sunset; Real Simple; and Travel and Leisure. The content on the mentioned properties included: Run of the video network with 15 and 30 second shortened videos from the custom long form Rockstar – Farm2Fan videos; Custom Native Touts driving to video landing page; Custom Lightbox unit with video embed; Standard display distribution targeting foodies, organic food and wine enthusiasts. Also, included in the campaign execution was a paid social amplification executed through Time Inc. as well as support paid media to extend the reach of additional BCMA social media content and an additional layer of paid social for extended reach and content distribution. In addition to the digital media buy and social amplification, a custom integration was executed with the launch of Time Inc.'s newest program – ExtraCrispy.com which leveraged the Time Inc. audience of more than 125 million unique visitors across its properties and integrate the California's Agricultural Rockstars – Farm2Fan content into the greater editorial campaign with a focus on food/brunch content - a trending content area relevant to California specialty crops used in recipes.

As the campaign was shifted from a combination of print and digital media to a fully digital campaign, monthly reporting was deployed. Given that the content was 100 percent digital, the BCMA team was able to adjust the content delivery strategy based on content performance/engagement. This more regular reporting advised a shift in November 2016 from custom ad units that were not performing as well to better performing ad units making for a more efficient media spend for the final month of the campaign.

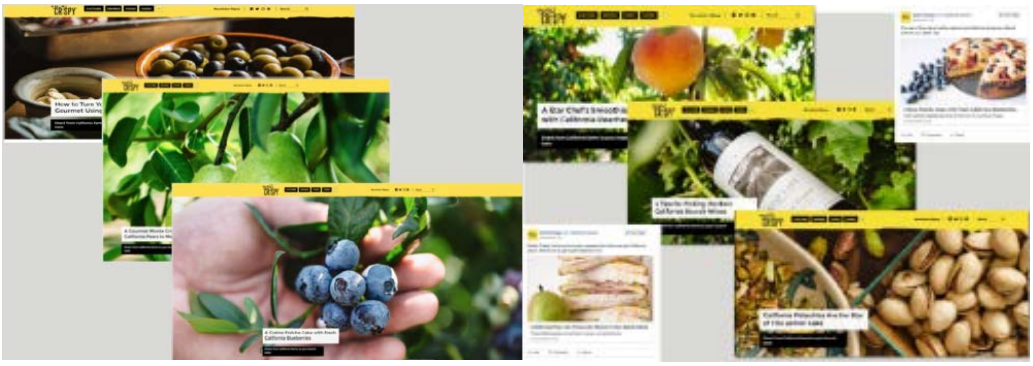
Stakeholder engagement was conducted with various California specialty crop organizations to identify the specialty crops and specialty crops producers featured in all promotional elements of the project. This includes the Agricultural Rockstar – Farm2Fan and On the Road videos; social media and blog content as well as event activations. This engagement allowed the project team to identify the broadest spectrum of in-season specialty crops and specialty crop producers to achieve the objective of promoting California's specialty crops statewide.

The Agricultural Rockstar - Farm2Fan video series and digital media campaign ran from August 1, 2016 - December 31, 2016. The Farm2Fan videos featured six California specialty crops and specialty crops farmers throughout the state and a "super-fan" of their specialty crops. The campaign also incorporated the driving hashtag #Farm2Fan. All video content was supported on the Time Inc. properties mentioned and was hosted on the Visit California Dream365 channel on the Visit California website and YouTube Channel (see link below). The six specialty crops featured in the video series were: California pears; California blueberries; California ripe olives; California wine-grapes/wine; California pistachios; and California peaches.

The Farm2Fan video series was relaunched and ran from July 19, 2017 – August 13, 2017. The relaunch executed a media spend to distribute the 30 second videos produced in 2016 during the peak season for all the specialty crops and specialty crop farmers and was featured on Facebook and Instagram. The strategy was to take advantage of available grant funds to get additional promotion and specialty crop awareness performance out of the video assets through a paid media spend to drive traffic to the content. Facebook and Instagram were targeted as these two platforms were the most cost-effective way to reach the target audience with the budget available.

Links to video content on Visit California site:
1. http://www.visitcalifornia.com/attraction/perfection-pride-and-peaches-how-california-grows
2. http://www.visitcalifornia.com/attraction/patience-precision-and-pistachios-how-california-grows
3. http://www.visitcalifornia.com/attraction/wisdom-warmth-and-wine-how-california-grows
4. http://www.visitcalifornia.com/attraction/people-passion-and-pears-how-california-grows
5. http://www.visitcalifornia.com/attraction/beauty-bounty-and-blueberries-how-california-grows
6. http://www.visitcalifornia.com/attraction/obsession-optimism-and-olives-how-california-grows

Custom brunch recipe content continued to be posted on the Time Inc. Extra Crispy platform and featured each specialty crop in the video series and linked the two content pieces to create the maximum discoverability of the Rock Star/Farm2Fan content.



Digital Asset Maintenance

Changes were made to the California Grown website to enhance the user interface which included a redesign of the site for better search optimization, and the installation of a new tool to call site visitors to subscribe to the weekly blog which featured weekly specialty crop recipes, DIYs, specialty crop farmer stories and other experiences that can be found in California. A new video environment (page) was built out to host all the California's Agricultural Rockstar - Farm2Fan, a new farmer's market festival video series, "On the Road" and other videos, which included an added video search function to the website. Agricultural Rockstar – Farm2Fan videos as well "On the Road" videos were integrated into the YouTube channel.

All the California's Agricultural Rockstar - Farm2Fan - Farm2Fan digital assets were integrated into a custom-built environment on the project partner, Visit California's website and Dream365 YouTube channel. The assets were also distributed to specialty crops farmers and stakeholders featured in the video content.

Blog and Social Media Content Development, Online Ad Purchases
BCMA reached consumers through a social media campaign using multiple social media platforms including Facebook, Instagram, Twitter and Pinterest. The content on the social media posts focused on California

specialty crops and were designed to encourage the purchase and consumption of California specialty crops. A total of 12.5 million consumers were reached on all social media channels.

Original content featuring California specialty crops was created by a blogger, who created 52 blog posts that highlighted a variety of specialty crops including: Blueberries, Avocados, Spinach, Arugula, Pumpkin, Olive Oil, Asparagus, Medjool Dates, Walnuts, Sage, Tangelos, Cara Cara Oranges, Naval Oranges, Fennel, Onion, Mint, Cucumbers, Radish, Flowers, Pistachios, Wine, Lemon, Cabbage, Carrots, Raisins, Pea Shoots, Pecans, Brussels Sprouts, Dried Plums, Strawberries, Almonds, Tomatoes, Kiwifruit, Tangerines, Pomegranates, Apples, Persimmons, Raspberries, Limes, Garlic, and Basil.

A new blog post feature was launched in 2016 which entailed a farmer Q&A for the Meet a Farmer section of the blog. The posts feature farmers of California specialty crops from April 2016 – December 2016 and featured 28 different specialty crops farmers from all over the state of California. The posts were distributed the same manner as the blog, through boosted Facebook posts, on Twitter, and on Instagram.

The new blog quickly became one of the top performing content pieces developed through the project and provided valuable direct feedback from consumers as to how much they supported California specialty crops producers and an unanticipated level of interest in gaining insight into a typical day for a California producer.

The recipe/DIY blog content proved to be very popular with consumers and affirmed that recipe and DIY content was of interest to consumers and on trend. Attached below are links to both the recipe blog landing page and the Meet a Farmer landing page on the California Grown website:

Recipe Blog Link: http://www.californiagrown.org/blog/ca-grown-mom/
http://www.californiagrown.org/recipes/guac-for-the-masses/
http://www.californiagrown.org/recipes/nectarine-arugula-pizza/
http://www.californiagrown.org/recipes/roasted-tomato-basil-soup/
http://www.californiagrown.org/recipes/black-mission-fig-and-almond-popsicles/
http://www.californiagrown.org/recipes/deep-dish-summer-squash/
http://www.californiagrown.org/recipes/watermelon-salad/

Meet a Farmer Link: http://www.californiagrown.org/blog/category/meet-a-farmer/

To increase the number of potential consumers reached the California Grown website was optimized (as mentioned above in digital asset management section) to include a strong email call to action in the recipe/DIY section of the blog encouraging site visitors to sign up for weekly recipes featuring California specialty crops. The weekly recipe newsletter was then refined to include the latest Meet a Farmer story as well, which incorporated two top performing content pieces that were delivered to e-newsletter subscribers. A Facebook campaign was run to encourage email sign ups as well.

Farmers Market Festival Video Series
The project funding for an originally planned online cookbook was reallocated to not duplicate a similar project being launched by another specialty crop organization and produced a series of videos to highlight specialty crops through agritourism experiences. The videos include, “On the Road to Apple Hill,” “On the Road to the Kelseyville Pear Festival,” “On the Road to the LA County Fair,” “On the Road to the Pumpkin

Festival," and "On the Road to a Sacramento Farmer's Market." The videos are featured on the California Grown website and YouTube channels and were promoted through social media platforms.

The new project presented an opportunity to invest project dollars in more video content, which was the most popular content medium on all significant social and digital platforms. The new series also brought specialty crops to life in the context of consumer experience, which has proved to be particularly popular especially with the number of video friendly platforms that are Internet based allowing for a much larger audience to learn about these unique opportunities throughout California.

Link to all "On the Road" videos:
Apple Hill: https://youtu.be/5hy5onp9m5U
Kelseyville Pear Festival: https://youtu.be/f14q7PDSD-E
LA County Fair: https://youtu.be/_HyKTNRSDvE
Pumpkin Festival: https://youtu.be/iBgufUXWzxA
Sacramento Farmer's Market: https://www.youtube.com/watch?v=b6NOUC4vl-4

Consumer Awareness Survey/Retail Promotions Sales Report
The project team reallocated the consumer awareness survey budget to fund a retail promotion event done in partnership with Costco Northern California. The promotion event was run in 52 northern California Costco warehouses from March 5-14, 2018 capturing approximately 22 California specialty crops products through in-store demos, signage and sampling. The event commanded a space in all warehouses that equated to a 40-pallet collectivized event space featuring a broad spectrum of California specialty crops and specialty crop products. In addition to the space dedicated to specialty crops, key specialty crop items were integrated into in-warehouse demos for customers to taste and encourage purchase of all items being featured. This format is unique to the Costco experience and is popular amongst Costco customers. Given the format of the promotion, the number of warehouse participating and the sheer volume of California specialty crops that are carried and sold by Costco this promotion event provided exceptional sales results which exceeded the target sales lift goal set in the project. The promotion opportunity originated from the project team's participation at the California Grocers Association (CGA) Strategic Conference at which the relationship with the Costco team was established.

The project team also worked with California retailer Ralphs to develop a retail promotion which included a radio spot by a celebrity spokesperson. Ralphs' Southern California contracts with the celebrity for weekly radio spots, and messaging promoting the purchase of California specialty crops was included in those spots. This activity was an additional no cost opportunity to leverage the audience of a top celebrity spokesperson who genuinely cared about promoting the purchase of local specialty crops. The opportunity originated from the project team's participation at the CGA Strategic Conference.

The project funded activation at two large consumer events; the Los Angeles Food and Wine Festival and the Oakland Eat Real events in recent months and several industry events. At each event, an abundance of specialty crops were featured along with information about California grown.

Los Angeles Food and Wine
The upscale Los Angeles Food and Wine event took place August 25 – 28, 2016 and featured cooking demonstrations by celebrity chefs and opportunities to reach key influencers.

The booth at Los Angeles Food and Wine provided opportunities to engage with the public through sampling, and recipes featuring California specialty crops. The blogger created a recipe that included nine different specialty crops and was sampled at the event by attendees. On display was a variety of specialty crops including California flowers, melons, citrus, pears, avocados, olive oil and dried plums. Total attendance was 15,000 consisting of 90 percent California attendees; 9.5 percent out of state attendees; and 0.5 percent international attendees.

Oakland Eat Real Festival
BCMA executed its activation at the Oakland Eat Real Festival, which drew approximately 8,000 foodies from the Bay Area to sample a wide variety of artisanal food. For the four-day event, the BCMA consumer activation included California pears donated by the California pear industry to be sampled as well as California dried plum sample packs donated by the California Dried Plum Board. The booth also incorporated a display of an abundance of California specialty crops including pumpkins, pears, herbs, melons, avocados, and several squash varieties.

CGA Conference
The project team met one-on-one with 17 California retailers at the CGA conference in September 2016. The event, which attracted 201 retailer/wholesalers, offered a chance for sit down meetings with retail buyers and marketing staff to discuss execution of retail promotional efforts in partnership with BCMA to promote the purchase and use of seasonal California specialty crops as well as California specialty crop farmers.

Fresno Food Expo
The BCMA team participated in the 2016 Fresno food Expo which incorporated onsite promotional advertisement placements displayed digitally during the run of the show. The promotional advertisement placements featured specialty crops farmer images produced during the Always in Season Campaigns which were run in 2014 and 2015. Additionally, the team partnered with the California Center for International Trade Development to address 37 international buyers at the show and notify them of the availability of California specialty crops for the Central and South American as well as the Southeast Asian markets. The session offered an opportunity for the international buyers to inform the BCMA team of market trends and/or desirability of particular crops. The event reported that it hosted 950 pre-qualified regional, national and international foodservice and retail buyers, and nearly 1,000 members of the public looking to discover food and beverages made in Central California. The event also provided an opportunity for stakeholder outreach as many specialty crops farmers/suppliers were in attendance.

Produce Marketing Association Fresh Summit
The 2016 Produce Marketing Association (PMA) Fresh Summit Event incorporated two stakeholder partners, the California Pear Advisory Board and the California Olive Committee. BCMA met with attending stakeholders to discuss ongoing promotions and potential for additional support that the program could offer.

Advertising effectiveness
In partnership with the project partner, Visit California conducted an Advertising Awareness Survey. The consumer awareness survey was tied to the performance of the California Agricultural Rockstar – Farm2Fan content and media spend. More specifically, the project team reviewed online metrics data to track effectiveness of all media elements, as well as invested in more video content.

BCMA engaged in several activities to execute and ensure the SCBGP funds were utilized to solely enhance the competitiveness of specialty crops. All farmers and crops selected for the "Rockstar" campaign were specialty crops and specialty crop farmers. All social media content was precleared by the BCMA team at regular content calendar meetings whereby an extensive list of specialty crops was referenced when deciding what crops to feature on social media and blog posts. All elements of the event activations at PMA, CGA, Fresno Food Expo, Eat Real, and Los Angeles Food and Wine were California specialty crop focused with over 20 specialty crops on display at the event.

The final step of oversight in ensuring the funds for the project were spent to solely enhance the competitiveness of specialty crops was extensive vendor invoice review which incorporated review and approval by the BCMA grant management team.

The contributions made by the project's partner, Visit California were made to the larger California's Agricultural Rockstars – Farm2Fan campaign which ran from August 1, 2016 – December 31, 2016. Their contribution consisted of an in-kind spend of approximately $3.6 million to build an online environment to host the video and digital content, expand the reach of the content on their robust online channels and integrate the campaign's messaging at key media events.

Goals and Outcomes Achieved

The project activities that most directly contributed to the achievement of the performance goals and measurable outcomes identified in the approved project were as follows: California's Agricultural Rockstars – Farm2Fan digital media campaign; Social Media and Blog Content development and Online Ad campaign; Farmer's Market and Festival Video Series, On the Road; Website and Digital Asset Management; Los Angeles Food and Wine Event; Oakland Eat Real Festival; Fresno Food Expo; California Grocers Association Strategic Conference; Retail Promotions with Ralphs and Costco Northern California/Northern Nevada; Advertising Awareness Survey conducted in partnership with project partner Visit California; Continuous Evaluation of online metrics for all project content/media elements. All these activities played a role in achieving the targets set for performance and measurable outcomes by way of key performance indicators and/or facilitating future events that resulted in measurable outcomes i.e. California Grocers Association Strategic Conference facilitation of Ralphs and Costco retail promotional efforts.

The project activities that had an indirect effect on the achievement of the performance goals were as follows: Stakeholder Outreach and PMA Fresh Summit. These two activities, though not direct contributors to the achievement of the performance goals of the project, facilitated the identification of specialty crops and specialty crops producers that would be featured through all project media and content elements.

The California's Agricultural Rockstars – Farm2Fan campaign (August 1, 2016 – December 31, 2016) delivered 50.5 million targeted impressions, which did not meet the project's target of 77 million impressions. This was due to the transition away from an initially planned print component, which counts total distribution as impressions, to a fully digital promotion campaign. This does not suggest a lesser performance as the transition to a full digital campaign provided a more targeted quantifiable number of impressions and engagement and opportunity for adjustment to ad media to better optimize media spend and performance. A rate of video engagement of 45 percent was achieved which was well above industry benchmarks of 22.5 percent and above the project's targeted engagement rate of 15 percent. The campaign also generated 102,000 clicks and 2.5 million video plays and exceeded the project's target visits of 60,000 to the Visit California

Dream 365/California Grown websites that hosted the content with a total of 67,773 site visits. The campaign also exceeded the project's target number of 40 media placements with 54 total media placements which included a robust digital activation and social media amplification of the Farm2Fan content.

The project's social media and blog content performed extremely well. The project performance targets for social media performance were set for total number of likes at 300,000 and 2 million impressions. Across all social platforms, Facebook, Instagram, Twitter, Pinterest the project generated a total of 15.8 million impressions – drastically exceeding the performance goal; a total reach of 11.2 million and 281 thousand quality engagements. There were more than 110,000 total post likes generated which did not meet the 300,000 likes performance goal. However, a more accurate measure of the success of the social media performance would be the above mentioned total impressions, total reach and engagements, which provide another layer of qualitatively and quantitatively reliable metrics of consumer interaction with content. Engagements are measured by progression of 3 key metrics of importance:
1. Retweets (robust) 2. Likes (robust) 3. Comments (most robust).

The blog producer added significant positive performance to the overall campaign and proved to be one of the most successful campaign elements due to the popularity of recipe and Meet a Farmer content amongst consumers. Total reach for the blog for the run of the campaign was 12.5 million and total blog views were 178,800. These two-key metrics reflect positive performance adding to the reach of the social media and blog campaigns.

The Los Angeles Food and Wine, Oakland Eat Real Festival and Fresno Food Expo added to the total consumer reach of the campaign with a combined attendance of 24,000 consumers of diverse demographics. The CGA Strategic Conference resulted in the target of at least two retail partners to secure to serve the performance goal of an increased sales lift by way of retail promotions of 3 percent.

The Ralphs promotion, though it brought heightened awareness for California specialty crops in the retail space, did not produce data tying to lift sales. However, the Costco promotion event conducted in March of 2018 generated total sales of $9 million and a lift of certain specialty crop product categories compared to the prior week of 9 percent drastically exceeding the project target of 3 percent.

The advertising awareness survey conducted in partnership with Visit California provided valuable insight into the performance of the California's Agricultural Rockstars – Farm2Fan media campaign. The survey was a national household survey of 53 million households. It indicated that the campaign overall awareness/recall of 15 percent of the surveyed households, which performed in the top five of all campaigns executed through Visit California channels. When rating household reaction to the campaign content, the California's Agricultural Rockstars – Farm2Fan media campaign received some of the most positive reaction and ratings amongst households surveyed, performing in the top 50 percent of all 14 content elements executed by Visit California in that year. Overall awareness compared to the year prior increased by 10 percent with a larger household base surveyed (7.6 million more households surveyed for 15-16).

The following benchmarks were utilized to set the project targets.

Benchmarks:

- Media performance
    - Impression delivery (benchmark- 59,511,082; Year 1)

  - Engagement with custom content (benchmark - 41,000; Year 1)
- Earned media coverage
  - Number of media placements (benchmark - 15; Year 1)
  - Impressions (benchmark- 13,402,594; Year 1)
- Sales of California specialty crops with retail promotions partner (benchmark – Current California specialty crop average sales)
- Advertising effectiveness:
  - Increased awareness of California specialty crops among target audience. A survey will take place in Visit California's fall Advertising Awareness Survey, to be conducted by SMARI in the fall of 2015.
  - Increased affinity for California specialty crops among target audience. A survey will be conducted by BCMA in the winter of 2016. Quarterly reporting of online metrics will also be used to track affinity for California specialty crops.

Targets:

- Media performance
  - Impression delivery (77,451,517)
  - Engagement with custom content (15 percent rate of engagement, 60,000 visits to food and wine content on VisitCalifornia.com and 300,000 likes on BCMA social media sites)
- Earned media coverage
  - Number of media placements (target: 40- media placements)
  - Impressions (target: 7 million Impressions)
- Sales Increase
  - Increased sales as reported with retailer partner in retail promotions (target – 3 percent increase in sales of California specialty crops in retail locations)
- Advertising effectiveness:
  - Increased awareness of California specialty crops among target audience (target: 25 percent increase from second year)
  - Increased affinity for California specialty crops (target: 7 percent increase)

Major successful outcomes of the project included:

- Media performance
  - The project delivered a combined 66.3 million quality impressions (highly targeted audience)
  - Achieved a rate of video engagement of 45 percent which was well above industry benchmarks of 22.5 percent and above the project's targeted engagement rate of 15 percent.
  - Generated 102,000 clicks and 2.5 million video plays and exceeded the project's target visits of 60,000 to the Visit California Dream 365/California Grown websites that hosted the content with a total of 67,773 site visits.
- Earned media coverage
  - The campaign also exceeded the project's target number of 40 media placements with 54 total media placements.
- Sales Increase

  - As mentioned, the retail promotion event executed with Costco Northern California/Northern Nevada was a great success generating $9 million in total sales and a 9 percent sales increase on 22 plus specialty crop products, compared to the prior week's performance over just a 10-day period. This promotion event resulted in a Return on Investment (budget spent to sales increase) of $130 generated in total sales for every budget dollar spent. The success of the event has led to plans for a late summer or fall promotion event and has prompted Costco Los Angeles to schedule their own summer promotion event end of July 2018.
- Advertising effectiveness:
  - Increased awareness of California specialty crops among target audience by 10 percent
  - The affinity survey dollars were reallocated to the retail promotion budget to generate sales numbers.

Beneficiaries

The specialty crop agricultural organizations that benefited from this project are as follows: Kiwifruit Administrative Committee, CA Association of Nurseries and Garden Centers, CA Pear Advisory Board, CA Asparagus Commission, CA Avocado Commission, CA Cut Flower Commission, CA Farm Bureau Federation, Agricultural Council of California, CA Almond Board, CA Leafy Greens Marketing Agreement, CA Cantaloupe Advisory Board, CA Walnut Board, Tomato Wellness Council, CA Blueberry Commission, CA Strawberry Commission, CA Artichoke Commission, CA Food Banks Association, Wine Institute, CA Dried Plum Board CA Fig Advisory Board & CA Fresh Fig Growers Association, American Pistachio Growers, Certified Farmers Markets of Sacramento, California Certified Organic Farmers, California Olive Committee, California Cherry Board.

The project benefitted more than 60,000 different specialty crops producers from the media campaign designed to increase California specialty crop visibility, awareness and overall sales. The California specialty crops and hence their producers include but are not limited to the following: Almonds, artichokes, dates, figs, raisin grapes, kiwifruit, olives, clingstone peaches, pistachios, dried plums, pomegranates, blueberries, walnuts, apricots, asparagus, avocados, dry beans, broccoli, brussels sprouts, fresh market cabbage, fresh market carrots, cauliflower, celery, sweet corn, daikon, eggplant, escarole/endive, flower bulbs, cut flowers, potted flowers and potted plants, garlic, table grapes, wine grapes, herbs, jojoba, kale, kumquats, lemons, head lettuce, leaf lettuce, romaine lettuce, limes, mandarins and mandarin hybrids, cantaloupe melons, honeydew melons, nectarines, nursery bedding plants, nursery crops, dry onions, green onions, parsley, freestone peaches, chili peppers, bell peppers, persimmons, plums, pluots, raspberries, fresh market spinach, strawberries, processing tomatoes, greenhouse vegetables, Oriental vegetables and watercress.

Lessons Learned

There were several lessons learned from this project, which have since been implemented through future projects. The shift from a print and digital media spend was perhaps the most significant learning/change that was made during the project. Though it impacted total impression delivery some, the shift allowed the media team to better target the ideal consumer audience, took advantage of a much more reasonable price point for digital/social media purchases vs. the extremely costly nature of print advertisement, allowed for more nimble execution of the campaign and permitting changes to the various digital advertisement assets to optimize performance of the content and resulted in a higher quality set of performance metrics that could be analyzed on a monthly basis. All projects following this project have been 100 percent digital for cost efficiency and

better content performance on more relevant digital media platforms being even further refined to target mobile users noticing the trend in marketing and advertising.

Additionally, the project team learned that key retail partnerships were the best means by which the project could positively impact the sales of California specialty crops and thus more time and resources were invested in fostering retail partnership through the CGA which resulted in an ideal promotional opportunity with retailers like Costco to maximize impact sales. This learning has been applied by way of larger budget allocations to retail promotions featuring California specialty crops.

Further, the Los Angeles Food and Wine and Oakland Eat Real events though they provided direct to consumer touch points and overall positively affected the awareness goal of the project, were observed to be a rather large expense for an unknown return. Thus, the project team has shifted promotional priority from consumer event activations of this nature to retail promotions budget and more digital content development with greater consumer reach potential.

Also, the popularity of video content amongst consumers led the project team to pivot from an originally planned online cookbook to produce and promote the On the Road farmer's market and festival video series which performed well on Facebook and the California Grown YouTube channel.

Lastly, the project team learned that additional investment retail promotion like that executed with Costco was a much better spend than what could be accomplished through the originally planned consumer awareness survey that the BCMA team was to fund and shifted those dollars to an activity that could generate the sales lift targets.

The only unexpected outcome was the no-cost online radio promotion executed in partnership with Ralphs and celebrity spokesperson. The project team had anticipated a cost to supply California specialty crop specific messaging to be read by a celebrity spokesperson but was pleasantly surprised to find that Ralphs had a pre-existing budget that covered the online radio spot.

The only outcome measure that was not achieved was the 77 million impression target and the affinity lift of 7 percent. However, as mentioned this was a direct result of losing approximately 42 million print distribution impressions that could not be quantified nor qualified beyond the distribution statistic. The lesson learned was that the print impression metric was not as valuable as the various digital media performance metrics that could be analyzed in a more real time fashion and in fact allow the project team to shift to better performing tactics. With respect to the unachieved lift in consumer affinity as it pertained to the survey conducted in partnership with Visit California and the survey forgone that was to be conducted by the BCMA team. As reported the project team did receive overall positive reaction to the California's Agricultural Rockstars-Farm2Fan content through the Visit California survey and though the affinity and awareness numbers declined by approximately 3 percent, more US households were reached. The BCMA team consumer survey was intended to contribute to the measurement of affinity lift, but the project team determined that the higher priority was to allocate dollars to generating the more quantifiable 9 percent sales lift that resulted from the promotion executed with Costco Northern California/Northern Nevada.

Additional Information

No additional information

USDA Project No.: 2	Project Title: Paso Robles Wine in the Lone Star State	
Grant Recipient: Paso Robles Wine Country Alliance	**Grant Agreement No.:** SCB15002	**Date Submitted:** December 2018
Recipient Contact: Jennifer Porter	**Telephone:** (805) 239-8463	**Email:** jporter@pasowine.com

Project Summary

Total United States (U.S.) wine consumption tops the world, yet per capita consumption dwarfs other wine producing nations, with the U.S. ranked number 58 at 10.42 liters per capita. Since California wine represents 57 percent of the U.S. wine market, California specialty crops will expand with either increased per capita consumption and/or increased California market share.

In Texas, a huge opportunity exists for California wine, as per capita consumption is only five liters per capita, 52 percent below the U.S. average, ranking Texas forty-third among U.S. states. Couple increased consumption potential with the immense size of the market, Texas being the second most populous state with 20.1 million adults over the age of 20, this is an irresistible and timely opportunity. A modest 10 percent increase in consumption, from 5 to 5.5 liters would equate to an additional 13.4 million bottles of California wine sold. This feasible increase would boost Texas from the forty-third to thirty-eighth U.S. state in terms of wine consumption. Finally, there is an opportunity to influence behavior towards California wine with those entering the alcohol beverage category, since Texas is the second youngest state in the union, with a median age of 33.6.

This project built upon the 2010 Specialty Crop Block Grant Program Project 6: *Paso Robles Distinct and Different Direct-To-Consumer Marketing Campaign*. This project used the previous research from 2011 and 2013 to track Paso Robles American Viticultural Area (AVA) direct sales and winery visits. The research results from the previous project provided consumer and market data which resulted in demographic and geographic targets. The current project then used the previously identified targets for their advertising, events, media, and trade outreach.

Project Approach

The media contractors planned and executed Paso Wine branding and event advertising, targeting the wine drinking consumer (Age 25 to 64 with Household Income (HHI) of $100,000+).

In 2016, advertising ran with the following partners: CBS Local, Centro, Instagram, LiveIntent, RGM Group, Scripps, Pandora, and Facebook. The advertising delivered 14.4 million impressions, 54.5 thousand clicks to pasowine.com at a $6.47 cost per thousand. Brand creative was developed by Piston at Paso Robles Wine Country Alliance (PRWCA) expense.

Optimizing from the prior year's performance, the more efficient 2017 advertising plan delivered 18.1 million impressions, 141 thousand clicks to pasowine.com at a $6.06 cost per thousand. The partners included: CBS Local, BrandExchange, Centro, Pandora, Facebook, Trion Interactive and Yahoo. Brand creative was developed by Noise13 at PRWCA expense.

Public relations and communications contractors researched, recruited and monitored activity from journalists, qualified bloggers and contributors to Texas publications who participated in one of the two media trips to Paso Robles. Custom itineraries were developed for the tour showcasing over 30 brands available for distribution in Texas.

The May 2016 tour hosted six journalists who write for the following Texas-based publications: Edible Houston, Houston Style, Delicious Mischief Radio, Dallas Wine Chick, Austin Chronicle, and Austin Food Magazine.

The May 2017 tour hosted six journalists who write for the following Texas-based publications: The Daily Meal, Texas Wine Lover, Dallas Morning News, CultureMap Houston, Texas Lifestyle Magazine, and Galveston Monthly.

The project held four Paso Robles Grand Tasting Tours (Houston and Dallas in 2016; Austin and San Antonio in 2017) to introduce Paso Robles wines to new buyers and strengthen the relationship with existing buyers (i.e., buy more wine, stock keeping units [SKUs] and brands).

The PRWCA Trade Committee compiled the trade invite lists, along with Facebook advertising, and outreach to trade associations (e.g., San Antonio Restaurant Association).

There were 30 wineries that participated in the 2016 events held on April 20, 2016 in Houston and April 21, 2016 in Dallas. These dates, unfortunately, coincided with historic flooding in Texas, which impacted trade attendance.

There were 20 wineries that participated in the 2017 events held on June 6, 2017 in Austin and June 7, 2017 in San Antonio.

Although canceled in 2016 due to flooding, the PRWCA did attend Austin Food & Wine in 2017, along with Houston Food & Wine Week. In Austin, the PRWCA poured 20 wines over two days from a dedicated tent, along with two sold-out wine seminars conducted by local Master Sommeliers. The Houston Food & Wine Week activities including three events for which the PRWCA poured a selection of Paso Robles wines. Texsom, the preeminent sommelier conference held in Dallas each August, introduced Paso Wine to an influential audience. In 2016, the PRWCA secured two tables at the Grand Tasting, pouring eight wines. In addition, Paso Wine was the exclusive wine at the Texsom Winter Retreat luncheon with 100 sommeliers and wine judges in attendance tasting six wines.

Two Buyers' Retreats were held, bringing qualified sommeliers and wine buyers to Paso Robles each October. Custom itineraries were developed for the tour showcasing over 30 brands available for distribution in Texas.

The 2016 tour hosted nine buyers from the following Texas establishments: Sixty Vines, Jeffrey's of Austin, Madrina, Gaylord Texan Resort & Convention Center, Omni Mandalay Hotel at Las Colinas, Parkside Projects, Winebelly, Odd Duck and WineTastic.

The 2017 tour hosted eight buyers from the following Texas establishments: Counter 3 FIVE VII, Jeffrey's of Austin, Blends Wine Bar, Lovers Seafood, Shisnei Restaurant, Veritas Wine Room/Boulevardier/Rapscallion, Grace Fort Worth, and Del Frisco's Double Eagle Steakhouse Plano.

Three surveys were conducted with Paso Robles wineries to track the impact of this project in relation to distribution, wine club members, and visitors. The online survey was sent each March to measure baseline, mid-project, and final progress with upwards of 70 wineries submitting data.

This project does not enhance the competitiveness of non-specialty crops as the PRWCA is dedicated exclusively to the promotion of Paso Robles wine, a specialty crop.

Over 30 wineries participated in this program by hosting media during the Media Tour, hosting trade during the Buyer's Retreat, submitting wine for major events and traveling to Texas for Grand Tasting Tour events. In addition, over 60 wineries provided data in three online surveys to track progress. The program would not have been feasible without winery participation.

The public relations and communications contractors researched and invited six writers and qualified bloggers to Paso Robles each May for a media tour, tracking media placements resulting from the trip.

The media contractors developed, negotiated and presented media recommendations for a digital advertising campaign to best reach the Texas wine drinking consumer.
Upon approval, both contractors purchased advertising space based on authorized spending, properly coded the advertising to track and optimize performance, and provided recap reports to PRWCA.

Texsom, Hotfire (Austin Food & Wine), and Food & Vine Time Productions (Houston Food & Wine Week) provided booth space and pouring opportunities at major Texas trade and consumer wine tasting events.

Goals and Outcomes Achieved

The project activities included the planning and purchase of digital advertising, securing placement and participating in three Texas events (Texsom, Austin Food & Wine, and Houston Food & Wine Week), planning and conducting four Grand Tasting Tour events, hosting Texas-based media for two Paso Robles media tours, hosting Texas-based sommeliers and wine buyers for two Buyers' Retreats, and conducting three benchmarking surveys with beneficiaries.

The improved reputation of Paso Robles wine creates higher demand for the product, ultimately leading to increased prices for the winegrapes. The United States Department of Agriculture (USDA) Grape Crush Report was reviewed to determine changes in pricing based on demand for Paso Robles wine grapes (District 8). Comparing 2015 to 2017 pricing, the value of the crop increased for key Paso Robles varieties. Cabernet Sauvignon, 49 percent of Paso Robles plantings, increased in value 8 percent. Merlot, 11 percent of plantings, increased 9.9 percent in value. Syrah, 7 percent of plantings, increased 15.2 percent in value. Paso Robles's leading white wine grape, Chardonnay, increased 7.2 percent in value.

The Texas Alcoholic Beverage Commission reports monthly per capita consumption of wine in Texas. Comparing December 2015 to December 2017, the start and end of this project, wine consumption increased 12 percent from 5,064,440 to 5,669,725 estimated gallons. Monthly Per Capita Consumption statistics are

based on gross excise tax collections by the commission and population estimates are from the Texas Comptroller of Public Accounts 'Economic and Population Forecast Summary'.

The goal of digital advertising was to increase overall visits and visitors to pasowine.com by 15 to 25 percent, and traffic from the Texas markets with advertising activity to increase by 25 to 50 percent. For the 2017 calendar year (year 2 of this project), overall traffic to pasowine.com was up 21.4 percent in sessions/visits (504,951 vs 415,930) and 35.96 percent with users/visitors (349,256 vs 256,873). In Texas, the results far exceeded goal, with an 817.65 percent increase in sessions/visits (71,549 vs 7,797) and 953.62 percent increase in users/visitors (58,476 vs. 5,550). Traffic from Texas was 17.45 percent of total traffic to the website, up from only 2.39 percent prior to this project.

Media tours were used to garner third-party endorsement of Paso Robles wine, with the goal of reaching 50 plus million readers through 12 journalists' work. Articles resulting from the hosted journalists had a potential audience of 79 million. Publications included D Magazine, My San Antonio.com, San Angelo Standard-Times, the Corpus Christi Caller-Times, the Abilene Reporter-News, the Lubbock Avalanche-Journal, Edible Houston, Dallas Wine Chick, and more.

Four Paso Robles Grand Tasting Tours were held with the goal of hosting 150 to 200 trade and 200 to 250 tickets paying consumers.

Houston- held April 20, 2016. The event, two days after historic flooding, sold out at 204 guests with 101 ticket buyers being 62 percent male, 81 percent HHI $100K+, 71 percent age 35-64, and 80 percent graduate or bachelor's Degree. The trade portion had 93 RSVPs, with 56 in attendance.

Dallas- held April 21, 2016. The event sold out at 200 guests with 95 ticket buyers being 49 percent male, 77 percent HHI $100K+, 78 percent age 35-64, and 82 percent graduate or bachelor's Degree. The trade portion had 76 RSVPs, with 70 in attendance.

Austin- held June 6, 2017, sold 150 tickets to 75 ticket buyers being 56 percent HHI $100K+, 68 percent age 35-64, and 90 percent graduate or bachelor's Degree. The trade portion had 59 RSVPs, with 80 in attendance.

San Antonio- held June 7, 2017, sold 105 tickets to 54 ticket buyers being 45 percent HHI $100K+, 69 percent age 45-74, and 90 percent graduate or bachelor's Degree. The trade portion was poorly attended, with only 26 RSVPs, partly due to a scheduling conflict.

All Grand Tasting Tour ticket buyers were added to the PRWCA's email database for future marketing.

Paso Wine was poured at three major Texas events: Austin Food & Wine, Texas Food & Wine Week and Texsom with the goal of expanding awareness by introducing attendees to Paso Robles wine, adding 1,500 to 2,000 email addresses to the PRWCA database. Currently, there are 931 active emails from Texas. Some email addresses were purged in late 2017 due to inactivity.

While email signups fell short of the goal, the PRWCA was able to add a third Texsom event into the program and self-funded two Paso Robles wine seminars at Austin Food & Wine, delivering more exposure for Paso

Robles amongst important trade and consumers. In addition, wineries added at least 3.2 thousand email addresses.

The two Buyers' Retreats brought qualified sommeliers and wine buyers to Paso Robles, with the goal of 90 percent of attendees increasing the representation of Paso Robles wines on their lists.

After both tours, 100 percent of participants had the same or an improved impression of Paso Robles wines, with 88 percent increasing their representation of Paso Robles wine, noting specific brands they planned to introduce to their wine lists.

Three surveys were conducted with Paso Robles wineries to monitor the impact of this grant project in relation to distribution, wine club members, and visitors with a goal of a five to 10 percent increase. The survey results met the defined goal. Project staff reported a 50 percent increase in Texans in winery databases that are now used for marketing (47 wineries reporting; 10,272 emails). There was an 11 percent increase in Wine Club members in Texas (48 wineries reporting; 3,055 members). Project staff reported a 4.3 percent increase in case sales in Texas through distributors (29 wineries reporting; 152 thousand cases). One reporting brand, Hope Family Wines, elected to take two price increases in 2017, which resulted in a short-term 50 percent decrease in case sales. Had that one brand been stable, there would have been a 16.2 percent increase in case sales in Texas.

As a result of this grant, Texans are more familiar and engaged with Paso Robles wines than before, as evidenced by the following outcomes:
1) Increase in users/visitors to pasowine.com by 953.62 percent.
2) Increase in wine club members in Texas by 11 percent.
3) Increase in case sales in Texas through distributors by 4.3 percent.
4) Sixteen Texas wine buyers purchasing more Paso Robles wine for their restaurant/shop lists
5) Four wineries securing distribution in Texas, increasing shelf/list space for Paso Robles
6) District 8 fruit selling at higher prices

Beneficiaries

This project benefited over 300 Paso Robles' winegrape growers and wineries through increased distribution and sales in Texas.

While visitors from Texas benefit most wineries with the ability to ship wine direct to Texas consumers, over 30 brands with distributors or seeking a distributor in Texas benefited the most.

Lessons Learned

The PRWCA learned the following lessons during this project:

Texans are very receptive to Paso Robles wine and advertising, leading to huge increases in website traffic, visitation, and sales. Due to this success and to continue the momentum, in 2018 the PRWCA self-funded advertising in Austin and Houston, as well as a Hospitality Suite at Texsom.

For a better chance of success, it is important to have winery contacts in the local market to help with date and venue selection, as well as trade invitations. The PRWCA was not directly responsible for tracking trade

attendance at the Grand Tasting Tours, therefore it was not always reliable. For future tour stops, the PRWCA will assume control by using third-party technology to compile lists of qualified trade.

Texas Alcohol & Beverage Control operates very differently from California, which presented challenges regarding venues and made the programs more expensive since distributors must deliver all wine for a fee. In addition, it was challenging to get wine without distributors into Texas, requiring extensive paperwork and fees to accept shipments.

San Antonio is not yet a viable fine wine market, with Grand Tasting Tour attendance a struggle and distributor analytics staff reporting the PRWCA was too early to target that city. A focus on Ft. Worth separate from Dallas would have been a better selection in retrospect.

Texas is a price sensitive state, with some wineries experiencing a significant sales slump when taking price increases. The good news is that sales appear to rebound the following year.

Due to the disappointing performance of the San Antonio Grand Tasting Tour, the PRWCA has researched technology to gain better control over trade lists for invites.

Hearst Ranch Winery was able to secure a Texas distributor as a result of the 2016 Grand Tasting Tour. That brand went from zero to 1,167 cases in 2017, increasing the presence of Paso Robles wine on shelves/lists.

It is important to get direct input from numerous sources on the ground in Texas to ensure the program is planned in a way that is most likely to succeed.

Additional Information

No additional information.

USDA Project No.:	Project Title:	
3	Creating Demand for California Dried Fig Ingredients	
Grant Recipient: California Fig Advisory Board	**Grant Agreement No.:** SCB15003	**Date Submitted:** December 2018
Recipient Contact: Karla Stockli	**Telephone:** (559) 673-0526	**Email:** kstockli@californiafigs.com

Project Summary

The purpose of this project was to increase purchase intent and usage of California fig and fig ingredients via a comprehensive ingredient development program educating target audiences on the value of domestically grown and produced figs and fig ingredients. This was accomplished through the use of credible research development chefs and food technologists to demonstrate the numerous possibilities of using California fig ingredients to enhance flavors, improve functionality, lower overall ingredient costs, support food safety and sustainability and improve nutritional value, all in order to increase demand for this California specialty crop.

This project aimed to address the 70 percent of California figs that competed with low value imports in commodity driven business segments resulting in a devastating effect threatening the economic viability of the fig growers, processors, suppliers and workers. Imports represented 60 percent of fig consumption. Due to this aggressive import pressure, the California fig industry requested funding to execute a complete ingredient development program to educate key target audiences about domestically grown and produced figs and fig ingredients from California. The key target audiences of the California market enhancement program were research chefs, cereal chemists, and food technology professionals that represented niche food categories with the most growth opportunities (sauces, baking, confectionary and snacks).

In 2013 to 2014, imports increased 241 percent from the base year of 2007 to 2008 (3,625 tons/12,372 tons). This project targeted product developers in niche food categories and provided development solutions with the most growth opportunity for clean labels in sauces, baking, confectionery and snacks. This project also provided the ability to conduct one-on-one appointments with 10 targeted national accounts, development of new recipes for school foodservice, and the creation of ingredient videos to communicate the solutions of California figs and fig ingredients. This digital format enabled the project team to reach 35,000 unique users in an online platform. The project created opportunities to shift sales from low-value commodity markets to higher value food segments while reducing import pressure.

This project built upon the 2013 Specialty Crop Block Grant Program (SCBGP) Project 6: *Creating Value-Added Demand for California Figs* (California Fig Ingredient Program). The main goal of this project was to shift usage of California fig ingredients to high-value niche markets instead of competing in low-value import dominated segments. The grant allowed the program to: 1) Establish a benchmark of 500 chef/food technologist attitudes/intent to use California fig ingredients; 2) Generate 75 new leads through new associations with Cereal Chemist and Food Technologist, including Fortune 500 companies such as General Mills, the J.M. Smucker Company and the Kellogg Company; 3) Reach an estimated 6,000 product developers with fig messaging via the Institute of Technology supplier shows and ingredient development meetings; 4) Develop ten new California fig ingredient product concepts for commercial use to demonstrate the full range of solutions to product development needs; and 5) Develop a California fig ingredient kit with samples and materials to use as fulfillment and for one-on-one appointments. Building on the foundation that

was created with the prior year project, the 2015 SCBGP project provided partial funding for continued ingredient development and participation at targeted shows to extend program awareness to shift usage, meeting the program objectives to create economic sustainable viability through increased returns to growers.

Project Approach

To establish a usage and preference benchmark, post-program chef and food technologist attitudes and intent to use California fig and fig ingredients survey data was used from the previously funded 2013 SCBGP Project 6. Out of over 500 respondents: 74 percent represented product developers from foodservice volume ingredient categories; 49.94 percent indicated use of dried figs. The survey also validated that the needs of the product developer were perfectly aligned with the solutions provided by California fig and fig ingredients:

- Nutrition: 37.89 percent were interested in dried figs for product development for nutrition.
- Functionality: 52.17 percent were interested in dried figs for product development because of functionality.
- Natural sweetener: 35.4 percent were interested in dried figs as a natural ingredient.
- Future development: 67 percent of respondents also indicated an interest in learning more about California dried figs and fig ingredients for product development.

Through the execution of this grant, the California Fig Advisory Board (CFAB) increased interested respondents from 500 to 1,300. Of those, 160 (12.3 percent) indicated an intent to use California figs and fig ingredients. The continuation of the California Fig Ingredient Program provided the opportunity to target and educate new potential users of California fig ingredients to shift usage and meet program objectives while setting the stage for continued future one-on-one product development appointments.

The CFAB negotiated participation and exhibit execution at the Prepared Foods Seminar in Chicago, IL August 2016. Ingredient nutrient sources for cleaner labels and functional application for deliciousness was presented by the CFAB to over 300 food technologists and research chefs in the target audience. In addition, seven new ingredient concepts were developed to demonstrate the functionality and versatility of California fig ingredients: Vegan Mini Burger with Fig Paste and Fig Juice Concentrate, Mostarda, Fig-Ketchup and BBQ Sauce, Singapore Fig Glazed Chicken with Fig Larb Salad, and Grilled Fig Pork Sausage. All recipes were at least 50 percent by weight specialty crop. On the second day, the CFAB presented *The California Fig Difference in Clean Labels* with ingredient tasting to further demonstrate the natural sweetness, hydrophilic humectant properties, stunning caramel color, and high fiber content which further differentiate California figs from low value imports. Participation at the Prepared Foods Research and Development Ingredient Seminar provided the opportunity to demonstrate the possibilities of California fig ingredients to the target audience, to encourage a shift in usage, and meet program objectives while building a database of potential users for future one-on-one product development appointments.

Customized California fig ingredient presentations were used during scheduled appointments and program activities. Presentation materials and ingredient brochures containing information on the benefits and application use of figs for ingredient development appointments and ingredient kit fulfillment. The customized presentations for each scheduled appointment were ongoing through the grant duration. A total of 10 product development appointments were conducted.

Institute of Food Technology (IFT) Supplier Nights were held in Philadelphia, PA, Los Angeles, CA, and Portland, OR. They were also held in Rochester, NY, Bonneville, UT, and, Battle Creek, MI. The CFAB presented and demonstrated the use of California fig ingredients to over 8,500 food technologists and research chefs within the target audience. In this effort, numerous California fig ingredients were sampled: whole dried figs, diced figs, fig nuggets, fig paste smooth, and fig paste conventional. Fig powder, fig fiber, and fig juice concentrate were also sampled, including recipes created for this project where applicable. The project team followed up with a total of 160 food technologists as a result of these events. Interest was generated from the presentation of California figs and fig ingredients. Participation at all IFT Supplier Nights provided the opportunity to demonstrate the possibilities of California fig ingredients to the target audience to shift usage and meet program objectives while building a database of potential users for future one-on-one product development appointments.

A potential targeted list of companies for product development meetings was developed. The aim of these meetings was to conduct educational California fig ingredient seminars to demonstrate the unique uses of California fig and fig ingredients in new products. This resulted in the identification of top tier companies interested in learning more on California fig ingredients for new product development meetings in 2017 and 2018 (32 percent). Developing lists were critical to identifying key targets within the defined target audience for continued and sustainable efforts beyond the project duration. A total of 10 product development meetings were held.

Ingredient appointments were conducted with the Culinary Ingredient Development team of Campbell's Soup and Pepperidge Farm. Ingredient appointments were also conducted with the Global Nutrition research and development teams from Quaker, Naked (juice and bars), Gatorade, Tropicana and Kevita. The CFAB also met with the research and development team at Tillamook. Two appointments were conducted with the ingredient development team for Fresno Unified School Districts. The purpose of participating in these ingredient development meetings was to motivate product developers to consider California figs and fig ingredients to provide solutions to "cleaner labels" and meet the functional needs as well as a nutritious and economic solution in school lunch and breakfast programs. The California fig ingredient application concepts were customized according to each company and foodservice product development need and presented to provide solutions to the companies for cleaner labels and other trends. California fig ingredients were also presented in natural form: whole dried figs, diced figs, fig nuggets, and fig paste (smooth). As well as fig paste (conventional), fig powder, fig fiber and fig juice concentrate. All expressed interest in developing new products featuring California figs. Participation at Ingredient Development Appointments provided the opportunity to demonstrate the possibilities of California fig ingredients to the target audience to shift usage and meet program objectives while building our database of potential users for future one-on-one product development appointments

The project team prepared and distributed 380 California Fig Ingredient Kits to interested product developers. Getting product into the hands of key decision makers in the product development world, to demonstrate the possibilities of California fig ingredients to the target audience.

The CFAB worked with a culinary nutrition consulting company to create and photograph seven new school foodservice recipes featuring California figs that met the nutritional and cost needs of school foodservice directors. Seven new school recipes were developed which included California Fig and Pork Moo Shu Tacos, California Fig Moroccan Chicken and Chickpea Tagine, California Fig and Curry Chicken Salad, California

Fig Flatbread, California Fig and Orange Chocolate Muffin Bar, Fig Granola, and California Fig and Nut Dip with Apple Slices. All recipes created were over 50 percent by weight specialty crops. New recipes and photography featuring California figs were essential for inspiring the identified target audience. They were well-received with the strong possibility to be featured on future school menus.

The CFAB participated in the California School Nutrition Association's (CSNA) Child Nutrition and Industry Summit May 6-8, 2018 in Universal City, California. The purpose of the conference was to establish relationships with California school foodservice influencers and share new recipes developed specifically for this audience to create interest and use of California figs and fig ingredients to this important target audience. As a result, 196 contacts were secured and new materials specific for this audience were distributed. Participation at the Child Nutrition and Industry Summit provided the opportunity to establish targets within the school foodservice space to ultimately shift usage and meet program objectives.

The CFAB worked with a video production team to create seven new videos featuring California fig ingredient products with a focus on demonstrating the nutritional and functional benefits in manufactured goods to provide solutions in product development. This vendor was responsible for the creative direction, concept outline, script development, writing of the seven videos. The CFAB also worked with research chef spokesperson Robert Del Grande to develop and complete video scripts. The seven videos were as follows: 1) California Figs and Flavor as a System; 2) California Fig Ingredient Forms; 3) California Fig Ingredients in Baking Applications; 4) California Fig Ingredients in Sauce Applications; 5) California Fig Ingredients in Rubs, Marinades and Dressing Applications; 6) California Figs in Snacking and Confectionary Applications; 7) California Figs in Savory Applications. The videos proved to be critical element for expanding the project reach to a broader audience via digital platform. The videos were initially posted on the Prepared Foods website and will be posted on the CFAB website in early 2019.

To ensure the new videos reached the target audience of product developers, the CFAB worked with Prepared Foods magazine, the leading publication for the product development audience with 40,000 subscribers every month. Prepared Foods focused on research and development, marketing and purchasing (i.e., the product development team) and guaranteed delivery to a group of influential and involved ingredient buyers. Much of the content was featured on Prepared Foods' website, www.preparedfoods.com/, which generated additional exposure in excess of 35,000 unique users and over 70,000 impressions monthly. The new CFAB videos were hosted on the Prepared Foods website and were promoted through weekly banner advertisements eight times with call to action to click to view videos. The banner advertisements also ran eight times in Prepared Foods' weekly eNewsletter (average number of subscribers is 18,517) and were featured in a custom video eblast (average reach was 16,000). These channels guaranteed that California fig ingredient products were top of mind among key decision makers in the product development space.

This project solely focused on benefiting the competitiveness of specialty crops.

Goals and Outcomes Achieved

The project's primary goal and purpose was to increase usage of California figs and fig ingredients in niche categories (sauces, baking, confectionery, snacks and further processing programs) to provide higher returns to growers and help stabilize the California fig industry from devastating import pressure. This was measured by the project's objective to positively shift usage and preference by 8 to 13 percent among target audiences of culinary and food technology professionals during the program, resulting in an increase of 15 to 20 new

products and menu items over the prior year. In addition, the project's target was to achieve $1.5 million in returns to the California fig industry over two years on increased revenues from niche market sales versus commodity sales. This was measured by internal records of shipments and grower returns reported to the CFAB. According to Mintel, new products containing fig ingredients were on the rise around the world for flavor, functionality and nutrition citing 50 percent of all new products with figs worldwide list a health and nutrition function on the label. Figs were named “2018 Flavor of the Year” by Firmenich, the leading ingredient flavor and fragrance company. According to Firmenich, fig flavored products grew more than 80 percent from 2012 to 2016. Firmenich credited the fig’s numerous health benefits plus sweet and satisfying flavor, and also noted the endless opportunities across a wide range of food categories.
Baseline data was established as part of previous grant results, including: 1) Chef and food technology professional attitudes and intent to use California fig and fig ingredients; 2) Revenues and returns to industry for sales to commodity outlets; and 3) Usage/ preference collected for new products through Mintel New Products Database. Chef and food technology professional attitudes and intent to use California fig and fig ingredients were measured through surveys conducted with food professionals associated with Institute of Food Technologists and Research Chefs Association. As a results of project efforts, 12.3 percent of food professionals indicated interest and intent to learn more about and use of California figs and fig ingredients. The California fig industry experienced over $1.5 million in returns, calculated using 2014 to 2015 base volume as adjusted to the 2017 to 2018 realized average price per ton. There were also 107 new fig products, a nearly 400 percent increase in new products. The project team also conducted 10 ingredient development appointments, which included top tier national brands and California’s second largest school district. The CFAB also executed a strong presence at eight conference and events. California figs and fig ingredients were sampled to 10,000 collective attendees in the project specific target audience. The CFAB also distributed 360 California Fig Ingredient Kits. Lastly, seven new videos, school service recipes and photos were created to further promote California figs and fig ingredients.

Beneficiaries

The primary beneficiaries of this project were the entire California fig industry, including more than 100 farmers, marketers, farm managers, and processors. The industry's 700 full-time and 3,500 part-time employees will benefit by retaining employment. Also, the communities where these employees reside (Madera, Fresno, Merced, Kern, Imperial, and Yolo Counties), which experience unemployment rates ranging between 6.4 to 24 percent, exceeding the state unemployment average of 6.2 percent, will also benefit from the fig industry's economic activity. This project also benefited manufacturing ingredient companies by offering solutions for cleaner labels with reduced refined sugar, sodium, and fat. Along with enhanced natural flavors, an excellent source of fiber, and good source of antioxidants while providing many nutrients of concern (potassium, calcium, magnesium, iron). In addition, the resulting new products will offer consumers "better-for-you" options contributing to a healthier society and ultimately allowing the California fig industry to target segmented consumers, such as "Fit Foodies," and the manufacturers that target these audiences.

The number of beneficiaries affected by the project’s accomplishments and potential economic impact of the project was approximately 4,500.

Lessons Learned

The California fig industry was very pleased with the results of this project and the positive momentum that was created. Along the path of achieving this success and industry support, the CFAB struggled to hire contractors with the skills and expertise to manage and execute objectives in the timeline established. This

was a critical part of the project (and caused program delays) because the project staff was small and needed contractors to move forward with the project.

Additional Information

No additional information.

USDA Project No.:	Project Title:	
4	Expanding California Thursdays – Promoting and Serving More California Specialty Crops	
Grant Recipient: Center for Ecoliteracy	**Grant Agreement No.:** SCB15004	**Date Submitted:** December 2017
Recipient Contact: Chris Smith	**Telephone:** (510) 845-4595	**Email:** chris@ecoliteracy.org

Project Summary

California public schools serve over 4.5 million meals each day. Federal and state funding provide 83.2% of the cost, an investment of $1.95 billion. California Thursdays® leverages the magnitude of this market to meet its objective of serving more freshly-prepared California-grown fruits and vegetables in school meals. California students face chronic diet-related public health challenges, such as childhood obesity and food insecurity. Improving school food – particularly by serving and promoting fresh, nutrition-dense, and delicious California fruits and vegetables – is a strategic and sustainable public health intervention. Expanding the use of fruits and vegetables in school meals increases the market share of specialty crop stakeholders as it simultaneously improves the health of students.

California Thursdays makes the procurement, serving, and consumption of specialty crops easier and more desirable. It demonstrates the potential to improve school food with an achievable first step of "just one meal, one day a week" coupled with the practicality of providing "turn-key" implementation and marketing resources. The program adopts a "collective impact model," with the Center for Ecoliteracy (CEL) serving as a backbone organization for a network of school districts to serve more freshly prepared, California-grown fruits and vegetables. Building on the successful statewide pilot, which grew the network from one to 15 to 42 participating school districts, the expanded California Thursdays program further enhances the marketability of specialty crops, creates opportunities for producers, increases access for underserved students, and improves student understanding of specialty crop agriculture.

The California Thursdays program timeliness and significance is evident to industry, consumers, and the media. Its potential to increase sales and competitiveness is recognized by industry: California Thursdays was named one of the "top three market movers for 2015" by Sysco and new product lines for school districts featuring California-grown food were developed by distributors Gold Star, AgLink, and Sysco. Its appeal to consumers is clear: evidenced by the bold images of fruits and vegetables that are the centerpiece of promotions. Its effectiveness at improving consumption is demonstrable: districts reported a 13% increase in student participation on California Thursdays in its first year. And outcomes related to raising awareness are noteworthy: earned media coverage with broadcast and online features resulted in a total of more than 240 million impressions.

School meal programs predominantly feed students who are eligible for free and reduced-price lunches, increasing access for underserved youth. The program illuminates the linkages from farm to school. During this grant period, original educational resources that are standards-based and explore the culture and history of California specialty crops and agricultural practices were created, assessed, and disseminated. The positive ramifications of combining an understanding of specialty crop history and practices with the experience of

enjoying the fruits and vegetables has been shown to change students' attitudes and behaviors, which can impact consumption habits for a lifetime.

This project builds upon the 2013 Specialty Crop Block Grant Program Project 12: *CA Food for CA Kids.* The project was the pilot statewide launch of California Thursdays. It resulted in a successful collaboration with 15 school districts that collectively serve 190 million meals per year. Participating districts reported increased serving and consumption of specialty crops. The pilot Collective Action Day (CAD) on October 23, 2014, with participating districts hosting local events across the state on the same day coupled with a communications campaign, built awareness through earned media coverage from over 90 outlets, including television, radio, front page newspaper, and online. The expanded program built upon the accomplishments of the pilot effort.

Project Approach

The CEL successfully accomplished all "Expanding California Thursdays" program activities. The integrated suite of program activities included three tracks: (1) market enhancement, (2) nutrition education, (3) program assessment and management.

Market Enhancement Activities
Activity 1(a)(1) Create artwork featuring six new California specialty crops.

The CEL selected, sourced, and photographed six new California specialty crops: apricots, beets, cabbage, chard, grapes, and watermelon. The CEL's Creative Director worked with a commercial food photographer to create the appealing images. They became part of a collection of 18 California Thursdays produce images that are featured prominently in a variety of promotional materials –posters, signage, and truck-wraps – and are made available free to participating districts for their use, further amplifying the importance of California-grown specialty crops as the centerpiece of the program.

Activity 1(a)(2) Design new marketing materials for school districts.

During the entire grant period, the CEL designed and disseminated a variety of promotional materials to school districts on three separate occasions that were aligned with events and convenings. The artwork for the promotional materials, such as poster templates, is also made available for free to participating districts for their subsequent production of additional items.

In preparation for the California Thursdays third CAD on March 17, 2016, CEL produced and distributed double-sided bilingual posters (in English and Spanish) promoting California-grown oranges, strawberries, and carrots. The 58 participating school districts, which included the third cohort of 16 new districts, received a total of 2,350 posters. The pilot RFP process for the truck-wrap promotion (see Activity 1(b) below) was also conducted with 12 participating districts in San Diego County timed to coincide with the March 2016 CAD.

During the two August 2016 professional development orientations for the fourth cohort of participating school districts, which included 13 new districts, CEL designed and produced aprons featuring a California-grown orange. These aprons serve as marketing tools to students at the point of purchase in school cafeterias.

New districts also received the full collection of produce images and poster templates on thumb drives distributed at the orientations.

In recognition of National Farm to School Month in October 2016, CEL encouraged all 71 participating school districts to conduct a Tomato Salsa Challenge, based on one of the three specialty crop lessons. To raise awareness, promote the tomato lesson, and incentivize the challenge, a social media contest was conducted (see Activities 2(a)(2) and 3(f) below). Responding to requests for additional student-facing materials for use in cafeterias, CEL designed and produced "clings," clear vinyl window decals for use on salad bar sneeze-guards and service line windows, featuring tomatoes, broccoli, carrots, lettuce, and oranges. CEL produced a total of 7,320 sets of the clings, each set containing all five produce images in sizes ranging from 3.25"x3.25" to 3"x6," and distributed them the districts for use in the more than 2,900 school sites within the California Thursdays Network in advance of the October Salsa Challenge.

Activity 1(a)(3) Produce, distribute, and promote educational resources to school districts.

As part of its promotional efforts to educate students and school communities about the availability of California specialty crops as well as where food comes from and how it reaches the table, CEL developed and promoted online educational resources. They include: "Five Things Educators Can Do," to encourage teaching students about fresh, healthy California food and, among other things, promoting visits to local farmers' markets; family-scaled versions of five California Thursdays recipes for children and parents to cook at home that emphasize California-grown specialty crops; and a special website supporting the program's regional collective impact effort in San Diego County with "Five Things Parents Can Do," (in English and Spanish versions) encouraging visits to "a farmer's market or grocery store that features locally grown fruits and vegetables." The majority of these efforts were produced through matching funds and they are distinct from the standards-based lessons created as part of the Nutrition Education track.

Activity 1(b) Provide funds to school districts, through an RFP process, to truck-wrap delivery vehicles with artwork featuring California specialty crops; provide delivery vehicle decals to school districts with remaining funds.

At the outset of the promotional efforts related to the first California Thursdays Network CAD, CEL produced a Styleguide, to encourage consistent and effect use of the California Thursdays produce images, which included a graphic display on the side of a delivery vehicle as a sample "rolling billboard." One innovative district immediately used the specialty crop images on a 22' truck and reported enthusiasm from the community. Inspired by this successful effort, during this grant period, CEL made available matching funds to districts that wished to use one of two approved truck-wrap designs for their delivery vehicles. In advance of the March 2016 CAD, CEL conducted a pilot Request for Proposals (RFP) process with 12 school districts in the San Diego County, which resulted in three districts wrapping a total of 11 vehicles with images promoting California specialty crops. The production process was more challenging and time consuming than anticipated, due to variations in vehicle size and shapes. Subsequently, the RFP was made to the full California Thursdays Network in advance of the October 2016 Salsa Challenge, which resulted in an additional 13 districts securing funding, for a final total of 24 truck-wrapped vehicles in 16 districts. Despite the initial production challenges, the wrapped trucks have been very well received in their school communities and the promotional effort was a tremendous success.

When it became clear that there would be funds available at the conclusion of the statewide RFP process, CEL continued to innovate and be responsive to needs in the field. CEL proposed to use the remaining funds to offer vehicle decals with produce images, approximately 4'x4' in size, to districts that would pay for installation. The decals were equally well received and 51 were installed on delivery vehicles. In all, 75 school district vehicles are wrapped or have decals with engaging, large-scale images of California specialty crops.

Activity 1(c) Conduct three student focus group sessions and produce a summary report.

CEL contracted with Brown Miller Communications to conduct three student focus group sessions to better understand students' attitudes about eating California specialty crops, their perceptions surrounding the benefits that specialty crops bring to their lives, and which messages and strategies resonate with youth. Focus groups were conducted with students in seventh and eighth grade in three locations across California (Sacramento, Monterey, and San Diego counties) in order to provide a statewide sample.

The focus groups were held during September 2016 with students from Seaside Middle School in Monterey Peninsula Unified School District, Millennial Tech Middle School in San Diego Unified School District, and Harriet Eddy Middle School in Elk Grove Unified School District. Participants were recruited according to three criteria: students in seventh or eighth grade who are proficient in the English language, qualified for free or reduced-price school meals, and comfortable speaking in a group setting. Every attempt was made to recruit students who reflected the ethnic and gender diversity of each school district. Each of the moderated focus groups lasted approximately 90 minutes.

Brown Miller Communications authored a Student Focus Group Report with a description of methodologies and key findings. CEL authored a Student Focus Group Summary with key findings and disseminated it to all 71 food service directors in California Thursdays Network. A sample of key findings include:

- General Attitudes on Fruits and Vegetables: Students enjoy eating fresh, unblemished fruits and believe they are healthy and beneficial, but are generally ambivalent toward vegetables.

- Prefer Local and Organic: On average, students slightly prefer locally-sourced foods over out-of-state, but would very likely choose organic/non-GMO options due to concerns regarding the use of pesticides.

- Perception of Agriculture: Students define their region as "agricultural" only if they can see a field on a regular basis. "Agriculture" generally has a positive connotation, although it can raise concerns of pesticides.

Nutrition Education Activities

2(a)(1) Develop three classroom lessons that examine the historical and cultural significance of California specialty crops.

Prior to developing individual lessons focused on California specialty crops, CEL conducted research and conceived of a framework for a curriculum that increases the opportunity for new lessons to be incorporated in formal classroom instruction. Initially, the plan was to create learning experiences for fourth grade students

that compliment that grade level's emphasis on California history. Subsequently, the framework was expanded to align with California science and social science standards creating developmentally appropriate learning experiences for third- through fifth-grade students.

CEL developed, designed, produced, and assessed three new lessons that focus on navel oranges (Oranges: A Taste of California Sunshine), cabbage (Investigating Cabbage Traditions), and tomatoes (Tomato Salsa Challenge). To create the lessons, CEL worked with a curriculum design technical expert in consultation with educators at Farm Lab at Encinitas Unified School District.

2(a)(2) Design publication of three lessons and disseminate them free online through California Thursdays network of school districts.

Following the educator assessments completed by Farm Lab, the full collection of lessons was revised, finalized, and published as a free download on CEL's website. A targeted email, with links to the lessons, was disseminated to the entire Network with encouragement to disseminate them further to educators, administrators, FoodCorps service members, and parents within each school community.

Program Assessment and Management Activities

Activities 3(a)-(i) Assessment-related Activities (listed below).

CEL worked with Resource Development Associates to successfully complete the following activities:

- 3(a) Create/conduct baseline survey of school districts participating in California Thursdays program.
- 3(b) Record baseline digital statistics for social media.
- 3(c) Record digital statistics for social media and record earned media count.
- 3(d) Activity removed from original work plan.
- 3(e) Create and conduct questionnaire survey of school districts participating in California Thursdays program.
- 3(f) Record digital statistics for social media and record earned media count.
- 3(g) Create and conduct questionnaire survey to educators assessing their use of the California Thursdays educational resources.
- 3(h) Manage projects, compliance, and regular reporting.
- 3(i) Monitor performance through data collection and assessment.

Project scope did not benefit commodities other than specialty crops.

Project partners include:
Two new cohorts of school districts joined the California Thursdays network bringing the total to 71 districts. The third cohort included 16 new district partners: Arvin Union, Buckeye Union, Cajon Valley Union, Chula Vista Elementary, Encinitas Union, Escondido Union, Grass Valley, Julian Union, Nevada Joint Union High, Pajaro Valley Unified, Palm Springs Unified, Rescue Union, San Ysidro Union, Santa Cruz City, Tustin Unified, and Vista Unified School Districts. The third cohort participated in the third statewide CAD on March 17, 2016. The forth cohort included 13 new district partners: Bakersfield City, Banning Unified, Centralia Elementary, Coast Unified, Escondido Union High, Fort Bragg Unified, Grossmont Union High, North Monterey County, Oxnard Elementary, Pasadena Unified, Rio, San Luis Coastal Unified, and

Woodlake Unified School Districts. The forth cohort attended one of two orientations in August 2016 and the Farm to School Month (October) statewide Tomato Salsa Challenge contest. For a complete list of districts and their enrollment and nutrition service statistics, please visit: www.californiafoodforcaliforniakids.org/network.

CEL produced new marketing materials during this period featuring six new crop images and contracted with an accomplished food stylist and photographer, who selected fresh and seasonal California fruits and vegetables for photographing. CEL engaged in the truck wrap promotion and contracted with Plumbline Studios, Inc., a design agency with many years of experience, to tailor the design to each district's individual vehicle requirements. CEL contracted with Brown-Miller Communications to conduct three focus group sessions across the state and to support public relations campaigns aligned with the March 2016 collective action day. CEL contracted a curriculum design technical expert to develop the California agriculture lesson plans and also partnered with Encinitas Unified School District's Farm Lab to evaluate the classroom lessons. CEL worked with a social media coordinator to provide continuous social media communication and engage with social media efforts at the participating school districts. CEL also worked with Resource Development Associates to develop data collection and assessment instruments and conduct analysis for progress reports and the final report.

Goals and Outcomes Achieved

California Thursdays is an effective implementation and marketing strategy that incentivizes sustainable systems change and provides opportunities, technical expertise, and turn-key resources to partnering school districts.

This project aimed to achieve two main goals: 1) increase procurement and serving of California specialty crops, and 2) increase awareness of California specialty crops. Achieving these goals was an ongoing and sometimes long-term process as each school district begins at a different stage of readiness to implement California Thursdays, including the necessary processes and activities to increase procurement, serving, and awareness of California-grown produce in school meals. As such, all districts have a different starting point (or baseline) from which progress can be measured and also progress at different rates. For some districts, increasing procurement of specialty crops by 10% or doubling the number of California Thursdays meals may be a short-term target, while for others this may be a longer-term goal.

Several school districts reported they have increased procurement and serving of California specialty crops following implementation of California Thursdays, while others have reported they are putting processes in place to increase procurement (e.g., outreaching to new vendors, inquiring about California-grown products). Additionally, detailed, baseline procurement data (2014-2015) has been collected from school districts with advanced data capacity. This data will be used to assess more quantitative changes in procurement of California specialty crops when updated information is available. CEL has undertaken several activities and created and distributed a variety of marketing and educational materials to raise awareness of California specialty crops (e.g., social media campaigns, posters, salad bar clings, aprons, truck wraps/decals, lesson plans). Districts have recounted the usefulness of these resources and some food service directors have noted increased awareness among students and community members.

CEL will continue to support participating districts, provide useful resources, refine data collection processes, and track program outcomes to assess progress toward these goals.

1. Increased procurement and serving of California specialty crops

Collecting procurement data from all California Thursdays school districts has been challenging. In many cases, distributors do not provide the origin of the produce to schools, or food is delivered weekly, making it difficult to discern produce purchased specifically for California Thursdays. For schools without advanced procurement data capacity, collecting and synthesizing provenance information is burdensome and requiring such onerous data collection could dissuade school districts' participation in the California Thursdays program. As a result, CEL has collected detailed, quantifiable procurement information from schools identified as having external support to facilitate advanced procurement data collection and synthesis.

For schools without advanced procurement data, CEL conducted several key informant interviews with Food Service Directors (FSDs) to collect self-reported information about approximate or estimated changes in the procurement and serving of California specialty crops since implementation of California Thursdays. Additionally, in the fall of 2016, CEL sent a survey to FSDs of the 58 school districts participating in California Thursdays Network during the 2015-16 school year. The surveys included questions about the serving of California specialty crops and frequency of California Thursdays meals.

Districts will have reported a 10 percent increase in purchases of California specialty crops, as reported by districts with advanced procurement data:

CEL identified 13 California Thursdays school districts with support and advanced data capacity, all of which are part of a regional collaborative in San Diego County facilitated by Community Health Improvement Partners (CHIP). Of these 13 school districts, 11 had baseline procurement data available for the 2014-2015 school year (reported below). However, procurement data for the 2015-2016 school year is not currently available; changes in procurement will be assessed once available.

During 2014 to 2015, California Thursdays school districts spent an average of 11.7% of their total food expenditure on California-grown foods (Figure 1). In comparison, non-California Thursdays school districts in the collaborative spent only 9.5% of their total expenditure on California-grown food, suggesting higher procurement of local foods in California Thursdays districts. CHIP estimates that ¾ of all California-grown food expenditures are spent on produce. Using this metric, CEL estimates that California Thursdays districts spent nearly half of all produce expenditures on California-grown fruits and vegetables (Figure 2).

Figure 1. Proportion of Total Food Expenditure Spent on California-grown Foods in 11 California Thursdays Districts in San Diego County, 2014-2015

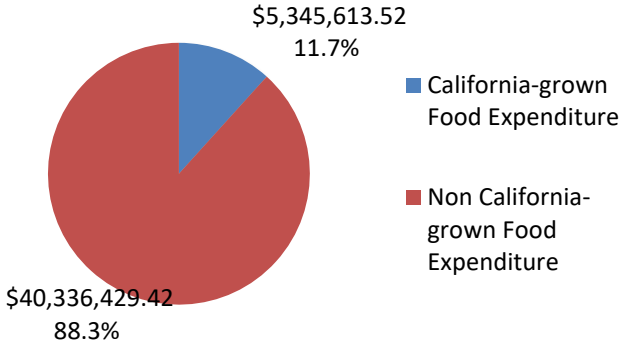
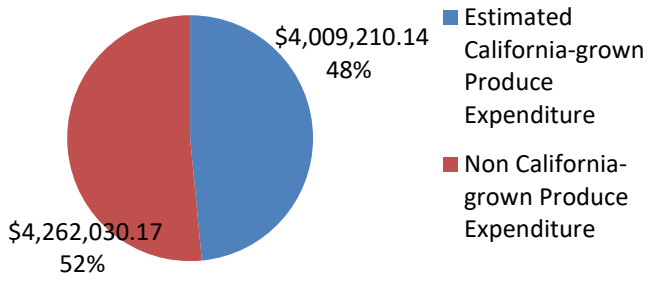


Figure 2. Estimated Proportion of Total Produce Expenditure Spent on California-grown Produce in 11 California Thursdays Districts in San Diego County, 2014-2015



CEL conducted key informant interviews with 10 FSDs, representing a diversity of regions and district sizes. Among the FSDs interviewed, six reported that they are purchasing more California-grown items. One FSD estimated that after implementing California Thursdays, their districts' "procurement of local produce has increased from less than one third to over 60%." Among the four districts who reported no increased purchase of California specialty crops, one explained that their district was already serving California-grown food every day. The others stated that although overall procurement of California products did not increase as much as expected, they are being more proactive about connecting with local farmers directly or they have communicated their preference for California-grown foods to their vendors.

Districts will have added an additional, new California specialty crop procured from a current or new vendor:

During the key informant interviews, five FSDs reported procuring at least one new California-grown item, including carrots and strawberries. Two FSDs reported they are procuring these items from new vendors. Several FSDs also noted they are expanding their recipe repertoire to incorporate more and new California-grown products. Of the 19 districts who completed the California Thursdays survey, 74% (n=14) reported serving at least one new California Thursday menu item during the 2015-16 school year. Five districts (26%) reported serving four or more California Thursday menu items throughout the school year.

Students in participating school districts will have seen a 100 percent increase in the number of opportunities to eat school meals containing fresh fruits and vegetables:

The California Thursdays survey administered in the fall of 2016 was used to collect baseline information regarding the number of opportunities to eat school meals containing California-grown fruits and vegetables. This survey will be administered again in the winter of 2017-2018 to assess any changes. Of the 19 districts who completed the survey, 79% (n=15) reported their districts were serving California Thursdays meals, including California specialty crops, at least once a week during the 2015-16 school year, while the remainder reported they served these meals at least once a month. The majority (81%) reported all school sites in their

district served California Thursdays meals in 2015-16; only three districts were not yet serving California Thursdays meals at all school sites.

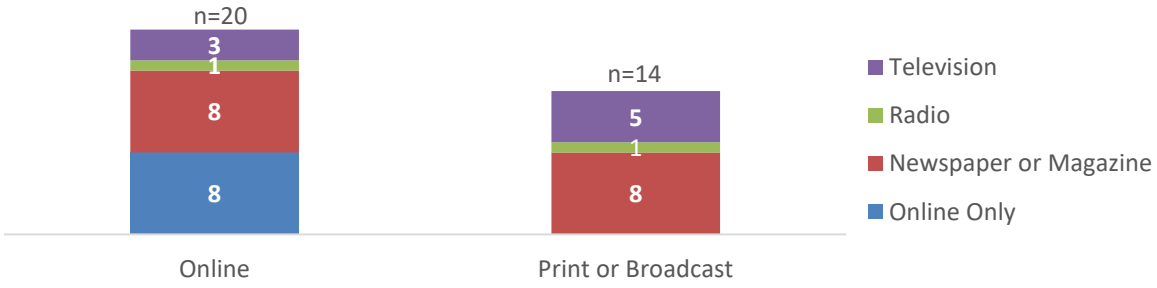
Moreover, 12 districts (67%) reported they plan to increase the frequency of California Thursdays meals, the number of California Thursdays menu items, or the number of participating school sites during the 2016-17 school year. Five additional districts (28%) reported they are currently brainstorming future steps to increase the serving of California-grown foods. Through the key informant interviews, two FSDs elaborated that they plan to expand opportunities to consume California specialty crops by incorporating California-grown fruits and vegetables into the breakfast and/or afterschool snack programs.

2. Increased awareness of California specialty crops

Earned media coverage will have included: (a) one national broadcast or print feature; (b) 10 local broadcast or print features; and (c) 20 web-based outlet features:

During the grant period, California Thursdays met its local broadcast/print and web-based feature goals, but did not have a national feature. California Thursdays earned 22 unique, local media features, including 14 print or broadcast features, and eight web-only articles (Figure 3). Twelve of the print and broadcast features were also featured online, resulting in 20 total web-based features. Through these earned features, CEL surpassed its target of 10 local or broadcast features, and met its goal of 20 web-based features.

Figure 3. Number of Earned Articles or Broadcasts Highlighting California Thursdays in March 2016 by Media Outlet Type (N=22 Unique Features)



Facebook will have received a 15 percent increase in "likes" and Twitter will have seen a 15 percent increase in re-tweets of California Thursdays postings:

California Thursdays also substantially boosted its social media presence. California Thursdays increased its average number of monthly Facebook posts, likes per post, and shares per post from 2.5 to 5.4, 13 to 20.5, and 1.1 to 2.9, respectively, from baseline (November 2014 to September 2015) (Figure 4). Similarly, California Thursdays increased its average number of monthly tweets, re-tweets per tweet, and hearts per tweet from 4.1 to 6.5, 1.7 to 4.9, 1.4 to 2.8, respectively (Figure 5). These surges in Facebook likes and Twitter re-tweets represent 58% and 100% respective increases over baseline, far exceeding the original target of a 15% increase in each metric.

Figure 4. Change in Average Number of Facebook Posts, Likes, and Shares per Month from Baseline to October 2015-December 2016

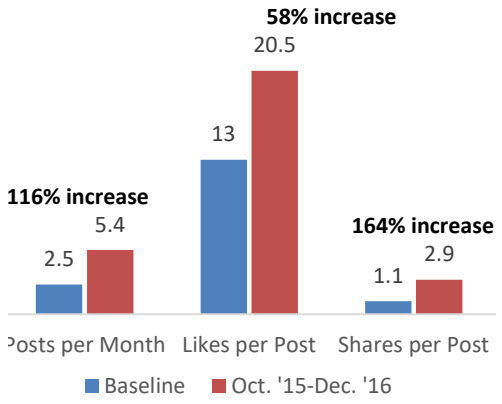
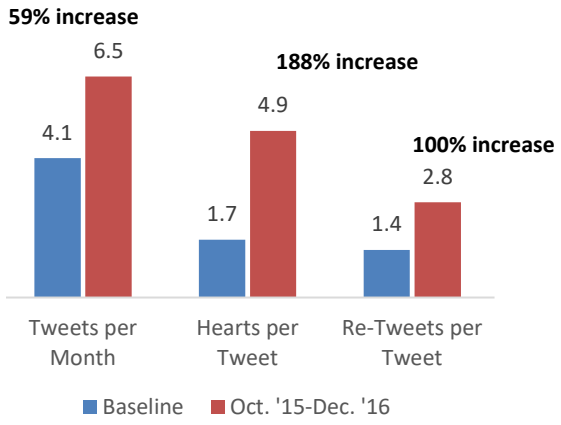


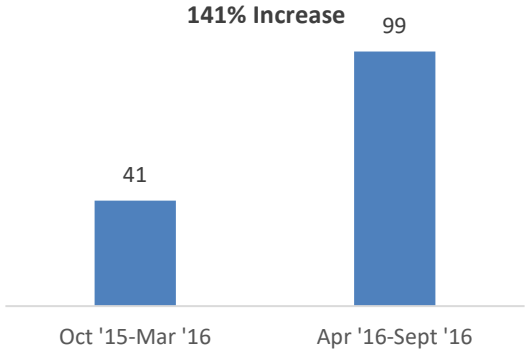
Figure 5. Change in Average Number of Tweets, Hearts, and Re-Tweets per Month from Baseline to October 2015-December 2016



Students in participating school districts will have been exposed to a 70 percent increase in the amount of marketing and educational materials promoting large images of California specialty crops in their schools and local communities:

CEL distributed new marketing and educational materials to school districts that increase awareness of California specialty crops. During the first half of the grant period, CEL distributed 2,350 posters depicting California-grown oranges, strawberries, and carrots to 58 school districts, representing an average of 41 posters per district. Throughout the remainder of the grant period, CEL produced and distributed 7,320 sets of salad bar clings featuring California-grown broccoli, carrots, lettuce, oranges, and tomatoes to 74 districts, representing an average of 99 clings per district. With the addition of salad bar clings CEL increased the students' exposure to California specialty crop marketing and educational materials by 141% (Figure 6), exceeding the original target of a 70% increase. Additionally, CEL distributed 170 aprons to the 16 new school districts joining the California Thursdays network in August 2016 to further raise awareness California specialty crops being served in the schools.

Figure 6. Change in Average Number of Marketing Materials Distributed to Districts from October 2015-March 2016 to April 2016-September 2016



Students and school community members in 12 districts will have seen school delivery trucks showing large images of California specialty crops:

CEL exceeded its goal of truck-wrapping or applying decals to delivery vehicles in 12 districts. During the grant period, CEL successfully engaged 16 districts, providing matching funds to truck-wrap 24 delivery vehicles and providing truck decals for an additional 51 vehicles. School district personnel reported the

wrapped trucks have been very well received by the community and have helped raise community and student awareness of California specialty crops being served in their schools.

Students will have reported an increased awareness of the availability of California specialty crops being served in their schools, according to the results from three student focus group sessions:

Brown Miller Communications conducted three focus groups with seventh and eighth grade students to evaluate students' awareness of California-grown foods, and identify key messages and communication strategies that resonate with youth. Generally, students had favorable attitudes towards fresh produce and indicated a slight preference for locally-grown fruits and vegetables. Most students reported they enjoy eating fresh fruit, although fewer enjoyed eating vegetables. From the focus group findings alone, it was unclear whether students were aware of the California specialty crops served in their schools. During key informant interviews, however, some FSDs noted changes in awareness. For example, one FSD stated, "[kids] ask now on Thursdays, where did [the food] come from? They now know that Bolthouse carrots come from up the road…this happens at multiple schools in [our district]; the kids want to know where the food comes from." Other FSDs noted they were unsure of changes in awareness, noting they did not have the means to identify or assess changes.

To help further raise awareness about California-grown foods in schools, students in the focus group suggested emphasizing where the product is sourced, including the name of the farm and nearest city, and telling stories about where the food was produced. Students also reported that highlighting fruit could be one strategy to encourage students to try new foods and eat locally-sourced foods. Other suggestions were to incorporate fruit into a greater number of dishes or create a "Fruit of the Week" program to introduce students to new varieties. Messages citing better taste, improved health, increased focus, better grades, environmental benefits, and boosting the local economy may also help motivate students to consume meals containing fresh, local produce.

Three educators will have seen and assessed the use of new educational resources made available to their districts:

CEL developed three classroom lesson plans for fourth grade, incorporating California history and one of three California specialty crops: tomatoes, cabbage, and navel oranges. Two educators at Farm Lab piloted and evaluated these lesson plans. Overall, all of the lesson plans were very well received, with the educators rating all lesson plans as "very good." The educators found the lesson plans very engaging and informative for students. One educator noted, "this engaging, experiential lesson is the sort that makes learning come naturally, so that sensory memory is made and information is absorbed and endures…into future food choices, grocery shopping, and appreciation for the historic accounts of food, health, plants, and agriculture." The educators reported that the lesson plans fit into the curriculum well, and they are likely to implement the lesson plans, or parts of the lesson plans, into future classes. These lessons were published and disseminated free online to school districts in the California Thursdays network to further increase awareness of California specialty crops.

Successful outcomes include:
CEL had several notable successes in increasing the procurement and awareness of California specialty crops. Through the resources and support provided to schools, it appears that CEL and California Thursdays is

helping schools increase the procurement and serving of California specialty crops. For example, in San Diego, on average, California Thursdays districts spent 2% more of their food expenditures on California grown foods compared to non-California Thursdays districts. Moreover, six out of the 10 FSDs interviewed reported they have increased procurement of specialty crops following implementation of California Thursdays, while five out of 10 mentioned they are also serving new California-grown fruits and vegetables. Additionally, 79% of the 19 school districts survey reported they are already serving California Thursdays meals, including fresh California-grown produce, at least once a week. Most districts surveyed, 67%, reported that they plan to further increase the frequency of California Thursdays meals or menu items in the next school year.

CEL is also successfully raising awareness of California specialty crops in schools among students and the larger community. Following the California Thursdays CAD in 2016, California Thursdays earned 22 local media features. Additionally, CEL provided matching funds for 24 truck-wraps and 51 decals for food delivery vehicles in 16 different school districts. These truck wraps and decals feature bold images of California specialty crops and serve as rolling billboards to raise awareness of California-grown produce served in school meals. To raise awareness in schools and the community further, CEL has also substantially increased its social media presence, doubling the number of monthly Facebook posts and increasing tweets by 59%. The number of Facebook likes and Twitter re-tweets have also grown by 58% and 100%, respectively, demonstrating the community's increased engagement in these campaigns.

Within the schools, CEL has produced and distributed 2,350 double-sided bilingual posters, 7,320 sets of salad bar clings, shareable poster templates, and aprons to raise students' awareness of California-grown fruits and vegetables available in their schools. With these new products created and distributed, CEL increased students' exposure to and promotional materials featuring California-grown produce by 141%. The exposure to these materials has increased students' awareness of and curiosity about California-grown vegetables served in their schools. Some districts have noted that students are more aware and interested in where their food comes from. CEL conducted three focus groups with middle-school students to identify more effective strategies and messages to promote awareness and education about California-grown foods. Beyond developing promotional materials, CEL created three lesson plans integrating California history and a different California specialty crop (navel oranges, tomatoes, and cabbage). Educators at Farm Lab piloted these lesson plans, and rated them all as informative and engaging. CEL disseminated these lesson plans free online to extend their reach and help educate more students about California-grown foods.

Beneficiaries

California growers and producers: 340 direct beneficiaries. The data from the San Diego County cohort revealed that California Thursdays districts spent an average of 11.7% of their total food expenditures on California-grown foods, nearly half of all produce expenditures on California-grown specialty crops, and 60% reported an increase in purchases of California-grown specialty crops. Extrapolating across 71 districts with estimates of average grower and producer beneficiaries results in this conservative figure. The formula for this figure includes the following factors: estimating that an average district purchases fruits and vegetables from a minimum of 20 California growers and producers (sometimes aggregated through one or more distributors) and adjusting for overlaps (i.e., one farm providing product to several districts) results in an average of eight grower and producer beneficiaries per district, which is then multiplied by 60% (reflecting the percentage of districts that reported an increase in purchases through the program) and results in the estimate of California

specialty crop growers and producers direct beneficiaries (i.e., 71 x 8 x .60) receiving increased income from school districts for their product.

California student consumers: 517,984 direct beneficiaries. This figure comes directly from the 33 districts hosting California Thursdays events at the CAD celebrating the forth cohort of new districts. Nutrition Service Departments at the districts collectively reported serving this number of California Thursdays meals, which feature freshly prepared California-grown fruits and vegetables, at 1,394 school sites on a single day. Given that some of the 71 participating districts did not report, even though they served California Thursdays meals (primarily because they were not hosting events), this figure is lower than the full number of student beneficiaries.

School community awareness of California-grown fruits and vegetables: 418,200 direct beneficiaries. Using the 1,394 school site figure reported above and estimating that the promotional materials (posters, clings, aprons, truck wraps, and vehicle decals) are viewed by a minimum of 300 students, staff, families, and local community members results in this number of direct beneficiaries. Note that this figure is likely to be low: total impressions for the third CAD on March 17, 2016 resulting from earned media equaled one million broadcast and 11.7 million web impressions and social media campaigns associated with CADs and the Tomato Salsa Challenge resulted in more digital engagements to raise awareness.

Estimates of total program beneficiaries are 936,524.

Lessons Learned

The “Expanding California Thursdays” program involved multiple, interrelated activity tracks engaging a large statewide network – with 71 districts encompassing more than 2,900 schools, 1.85 million students, and 11,600 nutrition service staff – with a range of overlapping outcomes related to the goals of increasing the procurement, consumption (participation), and awareness of California-grown fruits and vegetables in school meals.

Among the challenges were three significant disruptions, which CEL and program partners were able to overcome and that consequently reinforce the major lesson learned regarding flexibility, nimbleness, and the necessity for a backbone organization in a collective impact effort to remain alert to opportunities. The disruptions include two principle staff changes during the grant period. The founding program director moved on after the March 2016 CAD. With its strong connections and knowledge of the field, CEL was able to identify and recruit a highly accomplished new program director who had been a Nutrition Service Director. The program director was able to seamlessly join the CEL staff and successfully continue the ambition efforts associate with this grant program. In April 2016, the CEL education program director left the organization. Fortunately, the CEL executive director was able to assume direct management of the education-related program activities and work with long-time curriculum development technical expert contractor to seamlessly advance program goals and outcomes.

Two other disruptions to program efforts —the truck wrap promotion and the student-created video project— were addressed in two different manners. The complexities of tailoring approved truck wrap designs for vehicles with different dimensions and districts with different marketing graphics capacities to address the requirements necessitated the engagement of a design agency with many years of experience. This resulted in exceeding program objectives and outcomes. After exploring opportunities to develop and produce a student-

created video and consulting with three video production companies with expertise working with students, CEL concluded that it could not adequately deliver a video that would meet the requirements of the program and solely enhance California specialty crops. The program activity was discontinued and remaining funds were allocated to other innovative projects intended to reach the same target audience. Using social media, the "This is What Local Looks Like" Tumblr campaign associated with the San Diego County Collective Impact Effort, and the statewide "Tomato Salsa Challenge" social media contest met the target objectives.

An additional ongoing challenge involves the complexities of procurement data collection at the statewide scale of the program.

Activating a program and network of the scale of "Expanding California Thursdays" generates broad and granular outcomes, many of which are anticipated yet occur in innovative and unexpected ways. The most noteworthy unexpected outcomes are the program's successful and rapid scaling and replication. Growing from 42 to 58 to 71 public school districts is noteworthy. Much of this success is related to the strategies described above and to the power of providing motivated operations, like the participating school districts, with the turnkey resources that the program generated. Its replication, as evidenced by New York City Public Schools, the second largest district in the nation, adopting the program as "New York Thursdays" and planning effort with leaders in Nebraska to adapt the program statewide in their public school districts, demonstrate both the effectiveness of the program model and the power of the promotional and public relations efforts that have conveyed its value across the nation.

Additional Information

For an extensive collection of resources, including many detailed in this final report; a full list of the California Thursday network of 71 collaborating public school districts; and a media room with sample broadcast, print, and online earned media and the full collection of press releases, please visit www.californiathrusdays.org.

USDA Project No.:	Project Title: Increasing Demand for Canned and Frozen Apricots by Tackling Misconceptions	
5		
Grant Recipient: Apricot Producers of California	**Grant Agreement No.:** SCB15005	**Date Submitted:** December 2018
Recipient Contact: William Ferriera	**Telephone:** (209) 632-9777	**Email:** apricots@apricotproducers.com

Project Summary

The Apricot Producers of California (APC) priority was to increase demand for canned and frozen apricots by tackling misconceptions about the health benefits of processed apricots. Research on peaches shows canned/frozen peaches have equal or better nutrient levels than fresh due to levels of carotenoids also found in apricots. The University of California (UC), Davis study verified the same is true of canned/frozen apricots. Marketing efforts were conducted to share this information publicly, targeting dietitians, foodservice buyers, and other sources of health information with the goal to increase demand for canned/frozen apricots. Expected outcomes were to raise apricot prices by 3 percent (measured by National Agricultural Statistics Service data; represents $1.3 million in added annual returns to growers), stop the decline in acreage (measured by grower surveys), and influence foodservice buyers to use more canned/frozen apricots (tracked by foodservice contact follow-up).

The California apricot industry is struggling. Acreage is down 37 percent since 2004 per Apricot Producers of California records due largely to misconceptions about health benefits of processed apricots (canned/frozen), which are 68 percent of US apricot sales. "Fresh is best" campaigns have hurt the canned fruit industry which, due to smaller budgets, has struggled to effectively promote the nutritional benefits of canned fruits. Fresh fruit must be imported off-season, taking further sales from California producers who could be selling more canned apricots for off-season consumption. If these trends are not reversed quickly, apricot farmers in California will continue to lose processing contracts.

This project built upon the 2012 Specialty Crop Block Grant Program Project 16: *Promoting Healthy Fruits to Safeguard California's Peach and Apricot Industries*. In that project, California Cling Peach Board worked with Echo Communications to develop a consumer-focused promotional campaign that presented the results of the Oregon State University study that showed canned peaches to have equal or higher nutritional values than fresh peaches, relating to Vitamin A, C and E, folate, antioxidant, and carotenoid levels and found no significant decreases in any nutrients measured in the study compared to fresh peaches. The data used in this study and the post surveys indicated that consumers would increase canned peach consumption. This project focused on conducting a similar study for apricots which was expected to yield similar results.

Project Approach

UC Davis Apricot Nutrition Research Project was completed, and the results were positive. A study was submitted to The Journal of Food Science for peer review and publication and awaiting results.

The Website/Digital & Grower Communications was completed and launched at www.apricotproducers.com in time for the Apricot Producers' of California Annual Grower luncheon. Project Personnel created a

PowerPoint presentation highlighting project progress to date, including the preview of the UC Davis research, media coverage, social media coverage and the new website.
On the website content front, project staff continue to update the website to include new blog posts, while also reaching out to hundreds of school foodservice directors to promote California Apricots and encourage them to place their orders to the United States Department of Agriculture (USDA) and/or with their local broker.

Public Relations Outreach: The project staff worked with bloggers and media to develop stories featuring California apricots in all forms:

Influencers Outreach:
Outreach to health public health professionals: The project staff promoted the benefits of canned and frozen apricots to Registered Dietitians at the 2017 Produce for Better Health Foundation annual meeting and conference. In order to have extended one-on-one time with influencers, project staff recommended attending Pacific Coast Producers' Annual Heart of California Orchard and Field Tour to have three days with Registered Dietitians from across the country. Project Personnel organized a presentation by UC Davis researchers previewing the Apricot Nutrition Study. The UC Davis project director lead the presentation, which was extremely well received by the nutrition attendees.

Processors Outreach:
Outreach to current processors: The project staff reached out to current frozen and canning processors that set a nutrition platform that will enable processors to increase their current marketing efforts. The project staff, have provided processors with data and photos to include in future social media posts: Facebook, Twitter and Instagram. Additionally, project staff worked with Pacific Coast Producers and the research team at UC Davis to feature the UC Davis Apricot Nutrition Study at the 2017 2nd Annual Heart of California Orchard and Field Tour. This outreach has resulted in new processor partnerships, including one with Smucker's, and the Apricot Producers' website now features recipes from Smucker's that use California apricots.

Outreach to potential new processors: Considering the findings about the nutritional benefits of frozen apricots, Project Personnel hosted a conference call with the new product development team for Wyman's of Maine to brainstorm potential new products for this large frozen fruit company.

Additionally, with the efforts from project staff, Pacific Coast Producers has actively been promoting California Apricots on their company's Instagram page:
https://www.instagram.com/pacificcoastproducers1971/

Over the course of the project, it became clear to the project staff that the best direction to take in increasing demand for frozen and canned apricots was to spend more time working directly with the media, influencers, and processors. To that end, project staff did not attend the School Nutrition Conference, nor did the Academy of Nutrition and Dietetics show.

This project did not benefit any other commodity other than California specialty crop apricots.

Apricot producers were a big contributor to the support of the project and in many ways acted as a project partner. The project staff worked with them for two years on the Heart of California Orchard & Field Tour where apricots and the UC Davis Apricot Nutrition Study were spotlighted. One of the producers connected

Project Personnel with Smucker's, which resulted in website content for www.apricotproducers.com and which may also result in a long term marketing partnership. Apricot processors also supported the project with social media posts.

Goals and Outcomes Achieved

The project staff conducted a survey with participants from the summer's 2016 Orchard and Field tour to see if perceptions have changed about California canned apricots, as well as other canned fruits and tomatoes.

Here is one of the highlights from that survey:

Results from fresh vs. canned apricot samples analyzed at UCD

	Glucose (%)			Fructose (%)			Sucrose (%)			Total Soluble Solids (%)		
Sample	Fresh 0M	Canned 0M	Canned 3M	Fresh 0M	Canned 0M	Canned 3M	Fresh 0M	Canned 0M	Canned 3M	Fresh 0M	Canned 0M	Canned 3M
1	17.4	9.1	17.0	7.1	6.1	12.7	32.9	57.4	14.3	13.8	12.7	12.2
2	17.8	11.8	16.8	6.4	6.5	12.4	32.8	51.2	14.5	14.1	13.1	12.9
3	16.8	10.9	16.6	6.5	4.7	11.9	32.8	46.6	14.4	13.1	12.9	13.1
4	17.3	10.2	13.9	6.8	6.3	10.9	32.3	52.8	21.2	13.9	12.9	13.2
5	17.2	12.1	14.7	6.1	6.6	10.7	32.7	48.0	16.7	14.9	11.6	12.8
6	16.8	13.5	16.3	6.2	7.9	11.5	34.6	45.3	15.2	13.2	12.3	13.0
Average	17.2	11.3	15.9	6.5	6.4	11.7	33.0	50.2	16.1	13.8	12.6	12.9
Std. Dev.	0.4	1.5	1.3	0.4	1.0	0.8	0.8	4.5	2.7	0.7	0.6	0.4

Results from fresh vs. frozen samples analyzed at UCD

	Glucose (%)			Fructose (%)			Sucrose (%)			Total Soluble Solids (%)		
Sample	Fresh 0M	Frozen 0M	Frozen 3M	Fresh 0M	Frozen 0M	Frozen 3M	Fresh 0M	Frozen 0M	Frozen 3M	Fresh 0M	Frozen 0M	Frozen 3M
1	14.7	15.0	11.5	5.9	5.9	4.3	37.7	34.5	23.0	12.9	15.8	14.1
2	15.6	16.6	10.8	6.2	6.1	4.0	35.1	35.4	21.9	12.5	13.5	17.2
3	16.6	15.3	10.6	4.9	6.0	4.1	35.7	33.8	22.3	15.4	12.8	16.2
4	15.8	15.8	10.3	6.3	5.3	4.1	39.4	35.2	21.6	14.6	13.3	14.7
5	17.0	15.6	12.0	6.7	5.0	4.4	36.4	34.9	22.3	14.3	12.7	16.5
6	17.4	14.6	11.0	6.2	5.7	4.2	30.5	34.5	22.5	14.6	12.4	14.6
Average	16.2	15.5	11.0	6.0	5.7	4.2	35.8	34.7	22.3	14.1	13.4	15.6
Std. Dev.	1.0	0.7	0.6	0.6	0.4	0.1	3.0	0.6	0.5	1.1	1.2	1.2

Sugars (%)

	Fresh	Canned 0M	Canned 3M
Glucose	17.2	11.3	15.9
Fructose	6.5	6.4	11.7
Sucrose	33.0	50.2	16.1
Total	56.7	67.9	43.7

Apricot analysis 2016 at harvest

Results from fresh vs. canned samples analyzed at UCD

	Dry Matter (%)			Vitamin C (mg/kg)			Beta-Carotene (mg/kg)			Total Phenols (mg GAE/g)			Antioxidants in mM Fe/100g		
Sample	Fresh 0M	Canned 0M	Canned 3M	Fresh 0M	Canned 0M	Canned 3M	Fresh 0M	Canned 0M	Canned 3M	Fresh 0M	Canned 0M	Canned 3M	Fresh 0M	Canned 0M	Canned 3M
1	13.9	15.1	13.2	242	90	130	90.9	111.7	88.3	1.48	1.70	3.03	0.93	0.78	1.40
2	14.6	14.5	13.7	241	155	130	84.0	112.5	111.2	1.90	2.32	2.84	1.24	0.58	1.67
3	13.2	14.0	13.8	251	132	136	105.8	112.0	102.5	1.71	2.61	2.68	1.61	0.66	1.36
4	13.3	13.8	13.4	219	116	88	95.9	126.7	100.6	1.58	1.97	2.15	0.65	0.62	1.59
5	13.1	14.1	13.7	232	196	123	100.9	128.9	99.8	1.59	2.86	2.96	1.09	0.63	2.15
6	13.5	13.8	13.4	221	196	149	124.2	114.5	98.8	1.54	3.01	3.19	0.92	1.37	1.27
Average	13.6	14.2	13.5	234	148	126	100.3	117.7	100.2	1.6	2.4	2.8	1.07	0.77	1.57
Std. Dev.	0.6	0.5	0.2	13	43	21	14.0	7.9	7.4	0.2	0.5	0.4	0.33	0.30	0.32

Results from fresh vs. frozen samples analyzed at UCD

	Dry Matter (%)			Vitamin C (mg/kg)			Beta-Carotene (mg/kg)			Total Phenols (mg GAE/g)			Antioxidants in mM Fe/100g		
Sample	Fresh 0M	Frozen 0M	Frozen 3M	Fresh 0M	Frozen 0M	Frozen 3M	Fresh 0M	Frozen 0M	Frozen 3M	Fresh 0M	Frozen 0M	Frozen 3M	Fresh 0M	Frozen 0M	Frozen 3M
1	13.0	11.3	10.8	364	16212	9230	100.0	132.4	161.7	1.30	9.53	5.69	0.35	7.86	5.81
2	13.8	11.5	10.9	377	14222	10648	95.0	137.5	159.3	1.25	7.62	6.87	0.91	5.74	7.45
3	13.1	11.2	10.8	407	13684	9496	104.9	133.2	153.7	1.49	7.43	5.95	0.79	7.08	8.99
4	13.3	11.3	11.1	343	12681	10343	99.5	142.2	152.3	1.18	6.88	6.20	0.94	6.03	4.86
5	14.0	11.0	11.4	430	12884	8929	107.6	132.9	153.3	1.50	6.36	5.37	1.53	5.45	7.40
6	13.5	10.8	11.0	478	13573	10746	91.1	130.7	155.2	1.99	6.28	6.37	1.68	6.83	6.13
Average	13.5	11.2	11.0	399.8	13876.0	9698.7	99.7	134.8	155.9	1.5	7.4	6.1	1.0	6.50	6.8
Std. Dev.	0.4	0.2	0.2	49.2	1274.2	778.0	6.1	4.3	3.7	0.3	1.2	0.5	0.5	0.91	1.5

The long-term impact is to be determined. Once the study is published, the Apricot Producers will launch a national media campaign that will be aimed at increasing awareness about the nutritional benefits of California canned and frozen apricots. This in turn should encourage new sales of California apricot products.

Below is a survey taken after 2017 Orchard and Harvest Tour. University of California, Davis Apricot presentation was one of the highlights and that these decision-makers, moving forward, are now more likely to recommend canned fruits to the consumers.

The primary long-term goal of this project was to increase demand for apricots (creating market opportunities) as measured by the average crop value per ton annually reported by NASS. The benchmark for price per ton was the 2014 average price per ton ($777 per NASS), and the target was a 3 percent increase over that price ($800). Based on 2014 production, this would result in $1.3 million in additional grower returns. The project staff were able to reach the goal price of $800 per ton to growers.

The second long-term goal was to prevent further decline in California apricot acreage. The target was a zero percent drop in net apricot acreage from the benchmark of 10,150 acres in 2014 (per APC records). Acreage was measured by the annual acreage survey conducted by Project Director and will be published and shared with all growers and interested parties. The intermediate goal that will help achieve these long-term outcomes was to expand foodservice usage of processed apricots, providing a high-volume market for canned and/or frozen apricot sales. This was measured by the number of one-on-one meetings with school foodservice buyers that APC has during the project period and the number of buyers who committed to increased usage of

processed apricots. Since this outreach was not yet being done, the benchmark was zero. The target was to conduct 50 such meetings leading to approximately 20 buyers increasing usage of processed apricots.

To date, project staff have one new buyer of dried apricots; Choice Lunch of California. They serve over 300 schools (who do not participate in the national lunch program) across the state. This is a terrific win for the apricot industry as this company has more dollars to spend on apricot purchases than the national school lunch program. Additionally, project staff have met with leadership from the United States Department of Agriculture, as a part of the Orchard and Field Tour, and they have pledged to up their purchases of canned and frozen apricots.

Pacific Coast Producers: Heart of California Orchard & Field Tour 2017 Follow Up Survey — SurveyMonkey

Q4 How will this tour affect your future inclusion of canned fruit and tomatoes in your practice recommendations? Or what did you learn that you will now incorporate?

Answered: 14 Skipped: 0

#	RESPONSES	DATE
1	When fresh is not in season, I would recommend canned fruit - with the stipulation to drain and rinse off the extra sodium/sugar found in the liquid medium.	9/19/2017 11:42 AM
2	It's already impacting my story and message to reflect canned fruit/veggies as equal to fresh and frozen! I learned that some nutrients are actually higher in canned varieties.	9/18/2017 4:54 PM
3	I love to incorporate the story telling - I love the idea of saying 'grandma canned' - this is a legacy. Will also discuss how less than 5 hours from picking to canned.	9/18/2017 10:54 AM
4	I have always advocated these products to clients, but now I can do so in more detail having experienced this tour.	9/16/2017 4:43 PM
5	Was already praising canned fruit and vegetables but having seen it first hand, I can relate this experience in a more meaningful way.	9/16/2017 9:30 AM
6	Can foods hold onto more vitamin c and antioxidants than many fresh fruits and veggies	9/15/2017 6:31 PM
7	I would like to partner with PCP to tell the "harvest to can" story to other influencers and consumers. In addition, I have already shared the story regarding canned foods' "freshness factor."	9/15/2017 11:54 AM
8	I am going to use the information to educate supermarket dietitians on ways to promote canned fruits/veggies as an affordable and healthy addition to consumer's diets. I will also discuss the trends and can innovations that are happening so these can also be promoted.	9/15/2017 10:36 AM
9	I will definitely point out more of the nutritional benefits and try to clear up misconceptions about canned fruit and "syrup"	9/14/2017 6:22 PM
10	I was so excited to learn about your green initiatives and the safety of your canneries! I have already been sharing this information with associates and as far as general practice, I was reminded that I need to make sure to include canned tomatoes and fruit in my tours.	9/14/2017 3:24 PM
11	I will include more positive nutrition messages.	9/14/2017 2:12 PM
12	Will definitely be recommending canned fruit and tomatoes- in addition to buying them more often myself now. The research shared about apricots at UC Davis was a wonderful reference I plan to use in backing the recommendation. Also, all of the food waste reduction efforts and sustainability focus at the processing plants is something I will share.	9/14/2017 12:21 PM
13	While I was already a big advocate of canned fruits and veggies, this tour gave me new ideas on how to encourage people to incorporate more of them into their daily meals.	9/14/2017 11:33 AM
14	To focus on the benefit of reducing food waste	9/14/2017 11:14 AM

Some of the successful highlights of this project included: Increased media coverage for California Apricots, new website promoting apricot benefits, successful study completion with UC Davis and interest expressed by a leading journal re: publication of study, increased demand: project staff have asked California Apricot growers to plant more trees, customized Orchard and Harvest Tour to over 40 national decision-makers at leading retailers, United States Department of Agriculture, Sysco and US Foodservice. Attendees now are more likely to recommend canned apricots.

Beneficiaries

Beneficiaries include California apricot growers and processors. California apricots have an approximate annual crop value of $43 million per NASS data

More than 100 apricot growers, processors and supporting industries benefitted from this project. The economic impact has yet to be determined. Once the study is published, the Apricot Producers will launch a national media campaign that will be aimed at increasing awareness about the nutritional benefits of California canned and frozen apricots. This in turn should encourage new sales of California apricot products.

Lessons Learned

Flexibility was essential to success. The Orchard and Harvest Tours became key in convincing stakeholders about the benefits of California Apricot nutrition. The project staff had much more control here than would have had at a tradeshow.

Additional Information

Project website: www.apricotproducers.com

USDA Project No.: 6	Project Title: Expanding market opportunities for California prune producers through prune ingredient substitutes	
Grant Recipient: Sunsweet Growers	Grant Agreement No.: SCB15006	Date Submitted: December 2018
Recipient Contact: Nik Marchol	Telephone: (530) 751-5232	Email: nmarchol@sunsweet.com

Project Summary

Consumers increasingly demand “clean labels” on foods (familiar ingredients, with no additives/preservatives) and food makers, foodservice operators, and restaurants are pushed to comply. A 2013 United States (U.S.) consumer study found 50 percent of respondents avoided processed foods with high sodium and high fructose corn syrup (Hartman Group). Prunes are a proven substitute for sodium, sugar, and artificial colors. The project capitalizes on this to increase returns to California prune growers. With marketing aimed at makers of sauces and seasonings, the project goal is to boost grower returns with a prune ingredient line (concentrate, powder, puree, and fiber), providing an outcome of significant economic benefit to the 277 California prune growers (70 percent of U.S. prune sales) who own Sunsweet Growers.

This project was timely as recent California Department of Food and Agriculture and United States Department of Agriculture, National Agricultural Statistics Service (USDA NASS) report indicates California prune acreage declined from 86,000 acres in 2000 to just 50,000 acres in 2013, declining to 47,000 acres in 2015; the cause is waning economics compared to other tree crops. Economically viable prunes offer orchardists a diversification option versus nuts and other crops, and conversion to other tree crops is costly and takes years until a crop can be harvested. It is critical to improve grower returns on the prune specialty crop in order for the crop to remain economically viable for growers.

This project built upon the 2012 Specialty Crop Block Grant Program (SCBGP) Project 14: *Increasing Grower Returns by Marketing Phosphate Substitute for Food Processing*. This project launched a prune-based substitute for phosphates to retain moisture in poultry. Results of completed work include a dedicated website for prune products as ingredients, creation of promotional materials and establishment of relationships with key industry contacts/buyers. An accomplishment of promotional efforts is that the USDA recently approved the prune-based phosphate alternative as a meat processing ingredient. This project differs from the 2012 SCBGP Project 14 in that marketing efforts targeted sauce and seasoning manufacturers rather than meat processors, with focus on California prunes as substitute ingredient for sodium, sugar, and artificial coloring.

Project Approach

Activities performed to create market opportunities, enhance competitiveness, and increase returns for California's prune growers included:

1. Direct outreach: Trade advertisements were created and placed in the top food manufacturing trade industry publications, for both print and digital.

2. Promotional materials: Project materials were designed, developed, and printed into technical manuals that provided in-depth information on prune products and their applications in food formulation.

3. Exhibit at trade shows: Exhibited at the Culinary Institute of America 2018 World of Healthy Flavors event, highlighting the use of prunes as an ingredient substitute for food manufacturers, resulted in numerous sales leads. The purpose of trade show attendance was to connect with food manufacturers and deli/bakery operators who would be interested in using prune ingredients in order to reduce sodium, sugar and fat in their end products. For the trade shows, the project team set up a booth that was arranged to support only prune ingredients, equipped with prune product samples (diced, sauces etc.), culinary dishes using the prune ingredient, and technical literature.

4. Website: The Sunsweet Ingredient website was updated. Website updates included; organization around the food science applications of prunes, proving additional recipes and product specifications. The number of visits to the website was recorded as well as other relevant web data/analytics such as number of page views and source of visits via Google analytics and website page view counters.

5. Demonstrations: Attended and advertised at the International Dairy Deli Bakery Association and Institute of Food Technologists. These two trade shows allowed the project team to showcase prune ingredient substitutes to over 31,000 food science and technology professionals, buyers, and executives from the food manufacturing industry.

6. New recipe development: New recipes were made and shared on the Sunsweet Ingredient website. Brochures were also made and highlighted the use of the prune ingredients, which helped generate and develop sales conversations.

This project solely enhanced the competitiveness of specialty crops, specifically prunes.

A major project collaborator was CropSource. CropSource managed participation in the all trade activities listed above as well as presentations targeting customers such as General Mills, Wegman's, Wixon, Nestles, T. Marzetti, and Chop's Snacks. Additionally, CropSource managed trade advertising and trade events.

Goals and Outcomes Achieved

Both the goal and purpose of this project was to increase returns for California prune specialty crop growers. A successful market expansion is key for growers because it would increase grower returns by using prunes that would ordinarily sell into low priced industrial markets and use them in higher priced ingredient markets.

Activities completed for marketing efforts included:

- Creation and placement of trade advertisements in the top food industry publications, both print and digital. Both print and online advertising have proven to be a very successful and cost-effective strategy in the past for raising awareness prune products. Selection of specific trade journals and online websites was coordinated by the Project Manager.

- The design, development, and printing of technical manuals providing in-depth information on prune products and their applications in food formulation. Links for the manuals are listed in the last section of the report.

- Attendance and project exhibit at the Culinary Institute of America 2018 World of Healthy Flavors event, highlighting the use of prunes as an ingredient substitute for food manufacturers, resulted in numerous sales leads.

- The Sunsweet Ingredient website was updated and organized around the food science applications of prunes, proving additional recipes and product specs, which resulted in increased web traffic.

- The project team attended and advertised prune substitute products at the International Dairy Deli Bakery Association and Institute of Food Technologists.

- The new recipes developed for the project were shared on the Sunsweet Ingredient website and brochures. These products highlighted the use of the prune ingredient, which helped generate and develop sales conversations.

Key successful projects include:

- Treatt: Base business growing with new customers. The company purchased prune ingredient substitutes for the first time. The project continues to work with a major global beverage company with a targeted requirement $6 million in 2025.

- Kikkoman: Introduced food service sauce and consumer sauce using prune juice concentrate.

- Publix: Introduced four items of Smoke House line using prune ingredient substitutes for moisture and shelf life. Additional trials on sauces are in the works.

- Nestle Purina U.S.: After over two years of Research & Development (R&D), the company moved toward a commercial test run for cat food using prune juice concentrate in place of caramel coloring. First small order received.

- Nestle U.S.: Successful R&D using powder in meatball formulation now moving to full test run. Same division has newly initiated work on sauces using prune products.

- Chops Snacks: National marketer of high end beef jerky products reformulated line using prune powder thereby reducing sugar levels by more than 60 percent.

- Mitsuya Japan: Introduced trail mix featuring prune pieces to 18,000 Lawson convenient stores. Prunes are 20 percent of mix.

- Lawson Japan: Introduced pound cake using prune puree as butter replacement. Lawson now has listed four items using prune ingredients: pound cake, trail mix, plum jelly drink, Pokka iron drink.

- CP Thailand: One of largest food companies in Asia developed prune cake to be exclusively distributed in all 7-11s (more than 10,000) in Thailand starting December. If cake product is successful, it could lead to many other projects.

- Neto Israel: Largest food distributor in Israel concluded successful testing of prune ingredient substitutes in poultry and purchased additional product for testing.

- Starbucks Korea: Introduced walnut/dried fruit discs using about 20 percent prunes.

- J.O. Sims in UK: New application using prune puree in a chocolate bar with distribution in Marks & Spencer.

- Matthew Walker: Introducing new special Christmas Pudding in United Kingdom using diced prunes. Original purchase requirement was 6.5 metric tons of diced prunes for urgent production.

- Aldi South Germany: Introduced a prune bit/walnut blend for seasonal rotation.

Comparison of goals, baseline data, and accomplishments:

- Goal #1 – Increase annual sales to $20 million.
    - Actual result: Global Sunsweet Prune Ingredients in the U.S. market sales amounted to $10.6 million in the last 12 months of the project. This is 10 percent above the previous year.

- Goal #2 – Grower returns $4.8 million over the course of the project.
    - Actual result: Grower returns amounted to $6.89 million in the last 12 months of the project alone.

- Goal #3 – Generate increased sales leads
    - Actual result: Leads, as defined by companies that request samples to conduct research in their test kitchens and labs, totaled 559 leads from April 2016 through March 2018, a significant increase. Each lead is from a R&D professional within a manufacturer, ranging in size from small businesses to multi-national corporations. Importantly, leads accelerated by more than 80 percent during 2018 versus 2016. Sale leads in of 2018 reached 103, an increase of 212 percent over 2016.

- Goal #4 – Increase website traffic
    - Actual result: Website unique visitors were tracked during January-June 2018. The number of website searches was 3,587, an increase of 70 percent. This is attributed to the new website and viewers clicking on digital media, which redirects them to the site.

Advertisement impressions from July 2016 through June 2018 totaled about 3.4 million. Of these impressions, approximately 30 percent were from digital media such as e-newsletter leaderboards and e-blasts. Research conducted by the publisher Sosland showed that the 2017 ad in Food Business News had 48 percent reader recall in 2017. In 2018 the ad recall was 64 percent, one of the highest levels of all advertisers. Results from the e-blasts (typically sent to 10,000 subscribers) showed an average view rate of 15 percent and an average click through rate of 6 percent.

The time from initial contact to product order can be several years, as each project involves the project team partnering with each customer to develop formulation solutions. Some projects that will extend beyond the grant term are:

- Orkla Denmark: The chocolate coating project will use prune product substitutes with estimated tonnage 10-12 metric tons.
- Angelic Bakery: National marketer of sprouted bread products moving to incorporate prune ingredients through entire line for moisture benefits, with distribution in Costco.
- CJ Korea: Korea's largest food company is still working with prune powder to develop bone health product.
- J.O. Sims: Working with Soreen, a major malt loaf producer, to replace invert sugar with prune substitute. Initial results are positive.
- Lajonik Poldand: Snack company evaluating glycerin infused for incorporation in a fruit and nut cluster line.

A total of 31 new customers were added in the last 12 months of the grant term. Additionally, an ingredient broker network was established by Sunsweet and CropSource, which will aid in the selling process in the future.

Beneficiaries

The direct beneficiaries of this project are the 277 California prune growers. These growers annually provide prunes for 70 percent of U.S. prune sales and 60 percent of worldwide prune sales. According to USDA NASS, the production value of the 2014 U.S. prune crop was $209 million.

Lessons Learned

The global food manufacturing industry is working rapidly to reduce sugar and sodium in their products. This is a trend, not a fad, and the process will continue for years. This is good for the prune industry since prunes have applications that can aid in this effort. The overall project message worked best when it directly addressed the challenges of this industry e.g. "reduce sugar." Culinary positioning was not as compelling as originally thought.

Pure ingredient trade shows like Institute of Food Technologists worked very well. Trade shows geared to retail industry such as International Dairy Deli Bakery Association were not as successful at generating sales leads. However, a successful program was launched with Wegman's in their in-store deli which reduced salt and sugar content in sausages. This lead to the introduction of prepared foods with reduced salt and sugar in their deli. This success was able to generate interest in a major grocery retailer Publix, who has just launched a new pre-cooked marinated meat program, using the prune ingredients.

Trade advertising and e-blasts worked very well, more so than e-zines (advertorials). A high quality constantly updated web site is critical as all food product developers seek information on the web before starting R&D.

The technical materials were very important to provide not only usage instructions, but to generate a feeling of trust with the R&D industry.

The project team has compelling evidence of concept for many applications, which gives the project team confidence to continue the program into the future.

Prune concentrate and prune powder are natural and effective substitutes for caramel coloring. Interestingly an unexpected project outcome was that a major producer of pet food is very interested in using prune products as a substitute for caramel coloring in their cat food. After several years of R&D, they have ordered prune product for a trial production run of the cat food at their plant.

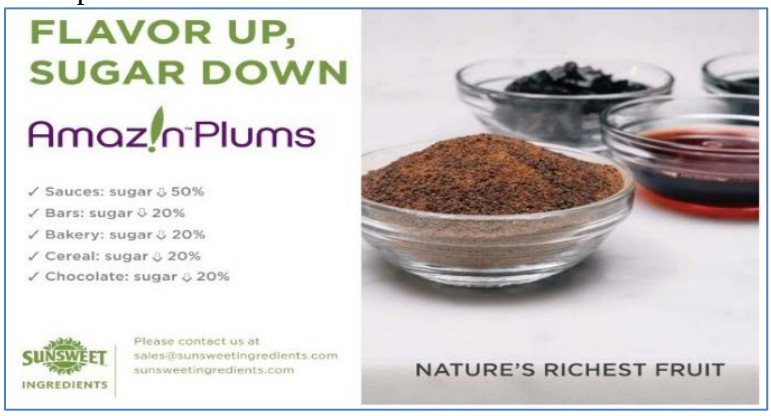
There is a very long lead time on the sales process for R&D ingredients, and the original goal of $20 million annual sales was not met. Many of the new customers that ordered product in the last six months of the project and are expected to reach the goal within the next two to three years. The project team would recommend being very conservative on initial sales estimates and to be highly persistent in the sales effort.

Additional Information

The new site conveniently outlines the food science applications of the prune ingredient, making it very helpful for food manufacturers to understand the usefulness of the product.
The link to the new ingredients site is here: http://www.sunsweetingredients.com/

Links to the technical manuals designed and printed using grant funds are here:
http://www.sunsweetingredients.com/wp-content/uploads/sunsweet-ingredients-bar-manual.pdf
http://www.sunsweetingredients.com/wp-content/uploads/Sunsweet-Ingredients-Sauce-2018.pdf
http://www.sunsweetingredients.com/wp-content/uploads/sunsweet-ingredients-protein-manual.pdf

Examples of ads are below.



USDA Project No.: 7	**Project Title:** Creating Demand for Lake County Winegrapes – Reaching Key Audiences to Increase Competitiveness	
Grant Recipient: Lake County Winegrape Commission	**Grant Agreement No.:** SCB15007	**Date Submitted:** December 2018
Recipient Contact: Debra Sommerfield	**Telephone:** (707) 279-2633, ext. 302	**Email:** debras@lakecountywinegrape.org

Project Summary

Lake County is a growing wine region that produces high-quality winegrapes and award-winning wines. As of 2013, it was home to approximately 8,700 vineyard acres and 32 wineries. The impact of an increasingly crowded marketplace and the limited production capacity of Lake County wineries presented challenges in building increased demand. Well over half of the wineries produce fewer than 5,000 cases of wine per year. Lake County production capacity is estimated at 459,500 cases, equivalent to 7,658 tons of winegrapes.

In 2013, Lake County growers harvested approximately 43,619 tons of winegrapes, well beyond local production capacity. Since 2013, 1,600 additional vineyard acres have been approved, an increase of nearly 20 percent in the county's total acreage, which will mean additional supply and continued sales pressure. Lake County growers also sell winegrapes to wineries located across California with most sold into Napa, Sonoma, and the Central Valley, with Napa and Sonoma generally offering higher prices. Lake County grape prices have fluctuated over the years, with average price per ton just 9 percent higher in 2013 than it was in 2002.

Farming costs including costs for labor continue to climb, shrinking the return to growers and in turn, possibly impacting the long-term financial viability of this industry in Lake County. To reverse this trend and ensure continued growth and vitality of this industry, this project was designed to create demand and increase average price per ton for Lake County winegrapes by reaching key stakeholder audiences.

A 2008 University of California Cooperative Extension (UCCE) production cost study for Lake County estimated cultural costs per acre at $1,871 for Sauvignon Blanc and $1,872 for Cabernet Sauvignon, Lake County's two major varietals, not including costs to harvest the fruit. In the years since, costs have continued to climb. In 2013 with an average price per ton of $1,407 (California Grape Crush Report 2013), returns to growers have been lean.

The long-term vitality of the industry is dependent upon two things: continued access to a market ready to buy the fruit and an increase in the average price per ton of grapes that keeps pace with rising costs. The purpose of this project was to create demand in this crowded marketplace that would drive an increase in the average per ton return on winegrapes by $50 per ton by harvest 2016.

This project built upon the 2011 Specialty Crop Block Grant Program Project 24: *Lake County Rising Promotional Campaign*. The project was designed to benefit Lake County growers and wineries with a multi-pronged approach to showcase the region and increase perceptions and awareness.

The project created a baseline of messaging and materials about Lake County wines and winegrapes, delivery of messaging at several promotional events geared toward different audiences (one for consumers, one for

trade, one specifically for sommeliers, etc.), and gaining an understanding of past and current perception and awareness of the region's wine and winegrapes.

This project builds on the messaging and activities of the last grant with activities designed to influence the broader buyer and trade segment, increase awareness and understanding of the region and provide a direct opportunity for product trial, which in turn, would positively impact the demand for Lake County wine and winegrapes.

Project Approach

Activities and Events:

- Multi-pronged outreach events in New York City, May 2017, with seminar presentations for media and trade and a pouring at a consumer wine tasting. Master sommeliers presented material developed under the grant to media and trade audiences including a wine tasting of curated wines representing the major varietals grown in Lake County. Six members of the media and nine members of the trade attended these seminars. The consumer tasting was an opportunity for Lake County wines to be poured from the *Wine Spectator* booth, reaching a broad base of approximately 600 consumers, furthering the quality message and reputation for the region.
- Participation in the Aspen Food and Wine Festival, June 2017. Brand ambassadors poured Lake County wine and shared information about the region reaching an audience of national and international trade, media, and 5,000+ high-frequency consumers over this prestigious three-day event.
- Participation in the TEXSOM Conference, August 2017, in Dallas, Texas, the largest and most well attended conference for sommeliers included an exclusive Lake County workshop and wine tasting for 100 sommeliers and pouring Lake County wines during a Tasting Break at the conference.
- Participation in Somm Con, November 2017, a sommelier conference and exposition in San Diego, California and the grand tasting at San Diego Bay Wine and Food Wine Festival (SDBWF). Somm Con activities included a 90-minute seminar on the Lake County wine region by a master sommelier and wine pouring during a trade and consumer tasting. The grand tasting at SDBWF reached 5,000 consumers.
- Provided media kits including thumb drives with course material and wine samples to 12 media who had been invited to the New York City event but were not able to attend.
- Held a technical tasting of Lake County high elevation volcanic wines at Momentum, 2017 grower seminar, May 2017 attended by over 100 Lake County winegrape growers and local media. (Note: This was an in-kind event funded by Lake County Winegrape Commission (LCWC) that included key messaging from the grant.)
- Presented Somm Boot Camp in Lake County June 2017 for 16 sommeliers from across the United States. This three-day intensive experience included tours of the major appellations of Lake County, presentations, and tastings of wines from the major varietals of the region. (Note: This was an in-kind event in collaboration with The Somm Journal and funded by LCWC that enhanced and expanded grant activities and incorporated grant messaging.)
- Lake County wines were poured by brand ambassadors at Chicago LuxeHome 11th annual Chill event in November 2017. The event attracted more than 3,500 attendees. (Note: This was an in-kind event funded by LCWC that enhanced and expanded grant activities and incorporated grant messaging.)
- Participation in first International Volcanic Wines Conference, March 2018. Project partner LCWC Director poured Lake County wines and educated attendees on Lake County wine region. (Note: This

was an in-kind event funded by LCWC that enhanced and expanded grant activities and incorporated grant messaging.)

- In May 2018, LCWC sponsored a two-day Sauvignon Blanc Experience. It included an eight hour technical workshop on Lake County Sauvignon Blanc attended by 120 trade and media, vineyard tours for trade and media, and a grand tasting for consumers attended by over 300 people. (Note: This was an in-kind event funded by LCWC that enhanced and expanded grant activities.)
- Participation at Unified Wine & Grape Symposium in the Regional Wine Pouring (January 2016, January 2017, January 2018) reaching key trade and media audiences.

Deliverables:

- Creation of presentation material on Lake County wine and winegrapes tailored to reach consumer, media and trade, and sommeliers with varying levels of technical information. This material was used during presentations made by master sommeliers as well as a brand ambassador during outreach events.
- Creation and launch of website course on Lake County wine region (www.lakecountywine.org). The website incorporated key messaging developed by grant activities, a video on the Lake County wine region, and high-impact drone videos of each region/appellation that adds a dramatic visual to the story of Lake County wine and winegrapes.
- Pre- and post-event survey to measure increase in familiarity with Lake County wines and winegrapes and value of course material in increasing familiarity with Lake County wine region. More than 320 pre- and post-event surveys were received from outreach events and visitors to the website.
- Development of Lake County Market Mapping research report by Full Glass Research providing an in-depth look at channels for wine sales and distribution and identify opportunities for future growth.
- Advertising in key wine publications including *Wine Spectator*, (audience 3,000,000; publication dates June, July, November 2017), *Food and Wine* magazine, (audience 911,000; publication July 2017) *Wine Enthusiast* Magazine, (audience 940,000; publication advertorial, June, ads, July, August, November 2017), *SOMM Journal*, (audience 67,000; publication June 2018) and *The Tasting Panel* magazine (audience 90,000; publication June 2018). Advertisements were timed to reach key audiences and build on outreach events. June 2018 advertisements were timed to promote the launch of www.lakecountywine.org website. Ad campaign on Facebook to promote the launch of www.lakecountywine.org website.
- Redesign of the Lake County Winery Association website to provide a mobile friendly platform to enable incorporation of key messaging and resources funded by the grant.
- Promotion of the range of activities and events was done on an on-going basis through monthly electronic newsletters, just-in-time e-mail blasts, press releases, as well as a Facebook campaign to growers, wineries, prospects and a range of interested individuals.

The overall scope of the project did not benefit commodities other than specialty crops.

The Lake County Winegrape Commission provided overall grant leadership and day-to-day execution of all grant-funded activities, events, and programs; managed all grant expenditures; and handled monthly grant billing with assistance from a consultant/project manager.

The Lake County Winery Association provided in-kind support at several events with hands-on assistance and communications including pouring at events, participation in design meetings for the lakecountywine.org website, and disseminating information about events and activities to association members and consumers via e-mail, web, and social media.

The County of Lake provided in-kind support with financial support for the advertorial published in the June 2017 issue of Wine Enthusiast magazine and has agreed to utilize the materials on the course website.

Goals and Outcomes Achieved

Goal 1 - Lake County wine region course materials will educate key audiences in four key markets about Lake County wine and winegrapes.

Activities that were completed to achieve this performance goal included participation in outreach events in four markets to reach key influencers including sommeliers, other trade, media, and consumers to educate them on the quality and desirability of Lake County wines and winegrapes, creation of an educational course delivered as a seminar and in an on-line format. The website incorporates materials developed during the grant, media kits and advertising in major industry publications. Success was measured using multi-phased audience surveys for events and website visitors.

Goal 2 - Partners will adopt or leverage the course material developed under this grant proposal with at least three partners adopting or leveraging the material.

Activities that were completed to achieve this performance goal included designing an easy to use, interactive mobile-friendly website with robust information about Lake County wine and winegrapes, publicizing the release of the website, and contacting partners to invite them to review the material and commit to adopting or leveraging it. Information included a video with a master sommelier narrating a short version on the course material developed under the grant and drone videos of seven of Lake County's appellations as well as additional information to communicate the key messages for Lake County wine and winegrapes. Success was measured in the number of partners who have agreed to adopt or leverage the material.

Goal 3 - Consumers, industry, media, and trade audiences will rate course material as good (4) or very good/excellent (5) on increased familiarity and awareness of Lake County wine and winegrapes.

Activities that were completed to achieve this performance goal included seminars for media, sommeliers, and trade at outreach events, one-on-one interactions with Lake County brand ambassadors at consumer and trade wine tastings, and launch of a comprehensive website on the Lake County wine region. Pre- and post-event surveys were used to measure ratings of the course material for outreach events. Post-visit surveys were used to measure ratings for the website materials.

Goal 4: Average return per ton over three-year cycle (2014-2016) for Lake County winegrapes will increase by $50 per ton by 2016.

Activities that were completed to achieve this performance goal included participation in sommelier, trade, and consumer events to educate key audiences about the quality of and build demand for Lake County grapes and wine, industry education events, and electronic and print campaign messaging. The measure of success

for this goal was the average return per ton for the three-year cycle of 2014 – 2016 compared with the prior three-year average return per ton for 2011 – 2013 using the annual California Grape Crush Report.

Goal 2, "Partners will adopt or leverage the course material developed under this grant proposal" is a long-term goal. The website course was launched during the last month of the grant. When the grant was written, the plan was to use Articulate Storyline to create the on-line version of the course material. However, stakeholder and partner input during year two of the grant resulted in the creation of a stand-alone website-based course instead. It includes a robust amount of information, visuals in the form of both video and still photography, quotes from the region's wine growers and winemakers, and key messages for the region, providing visitors and partners with an excellent platform for education. Work is underway to add a learning management platform that will include a quiz and certificate of completion for the course. This website offers a lot of promise for the future in educating key stakeholders about Lake County wine and winegrapes that will be used by a wide variety of partners and visitors. Response from partners was very positive with five agreeing to use the materials and help publicize the website.

All goals were accomplished. The chart below provides a comparison of actual accomplishments for each goal.

	Target	Benchmark	Outcome
Increase in familiarity with Lake County wine and winegrapes for outreach event attendees by 10%	10 percent increase	Pre-event survey	Post-event survey
Sommeliers, Trade, & Media ratings of somewhat familiar, very familiar, or very very familiar		62 percent	75 percent rate as good or very good/excellent
Consumers ratings of somewhat familiar, very familiar, or very very familiar		41 percent	83 percent rate as good or very good/excellent
Adoption or leveraging of course materials by at least **three** partners	3 or more partners	None	Number of Partners
Number of partners who agree to adopt or leverage course materials			5 partners
Consumers, industry, media, and trade audiences will rate course material as good (4) or very good/excellent (5) on increased familiarity and awareness of Lake County wine and winegrapes.	70 percent	None	Post-event or website visit survey
Sommeliers, trade and media rating material as good (4) or very good/excellent (5)			95 – 100 percent rate as good or very good/excellent

	Target	Benchmark	Outcome
Website visitors rating material as good (4) or very good/excellent (5)			80 percent rate as good or very good/excellent
Increase of at least $50 in the average return per ton for Lake County winegrapes over the three-year cycle of 2014 – 2016.	$50 increase	2011 - 2013 average return per ton	2014 - 2016 average return per ton
Average return per ton based on annual California Crush Report		$1,328.02	$1,596.02

Goal 1: Lake County wine region course materials will educate key audiences in four key markets about Lake County wine and winegrapes. Performance measure: Pre- and post-course survey responses. Benchmark: Pre-course survey responses. Target: 10 percent improvement in increased familiarity and awareness.

Outreach events were held in four geographic areas to educate key audiences about Lake County wine and winegrapes. A survey process was used to measure increased familiarity for participants at all events including table cards for the pre-event survey, followed by an on-line post event survey. Survey results for this report were aggregated to demonstrate increased familiarity across two audience categories: sommeliers, trade, and media; consumers.

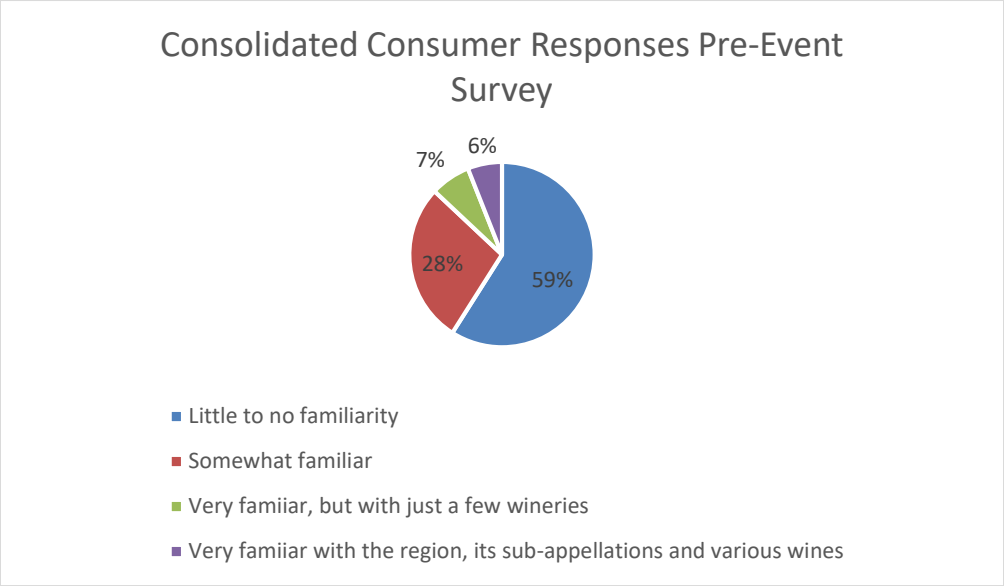
Sommeliers, Trade and Media
Sommeliers, trade, and media were reached at outreach events held in three locations: New York City, NY; Dallas, TX, and San Diego, CA. Responses from all events were consolidated to provide this analysis.

The following question was asked before the event and again in an on-line survey after the event: Please choose the description below that most closely matches your familiarity with wines from Lake County. There were 76 responses to the pre-event survey and 64 respondents to the post-event on-line survey. Respondents who identified themselves as Not Familiar fell from 38 percent in the pre-event survey to 25 percent in the post event survey. A similar result was noted in the percentage of respondents who identified themselves as Somewhat Familiar. In the pre-event survey, 44 percent of respondents said they were Somewhat Familiar with Lake County wines. That percentage rose to 59 percent in the post event survey. These results demonstrate a 13 percent to 16 percent increase in familiarity with Lake County wines and winegrapes.

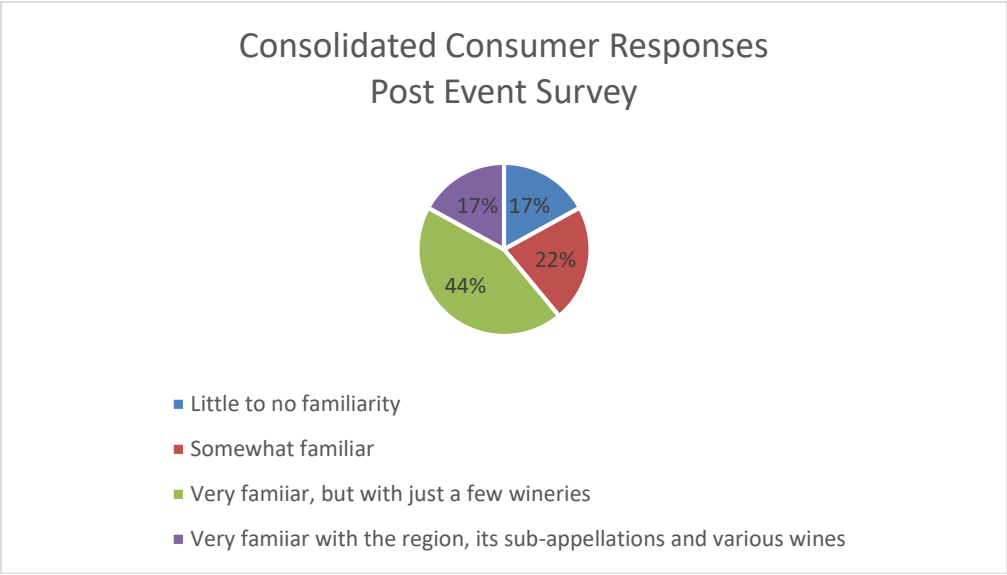
Consumers
Increased familiarity was measured in four consumer events including three planned activities under the grant (Aspen Food and Wine Festival, San Diego Bay Food and Wine Festival, New York City consumer tasting) and one additional in-kind event (Chicago). Table cards were used to gather pre-event feedback. There was a total of 82 responses gathered from consumers at all events.

This was followed with an on-line survey post event. Questions across surveys varied slightly. The results below reflect a consolidation of responses to similar questions to measure increase in consumer familiarity after tasting Lake County wine and talking with Lake County brand ambassadors at each event.

The chart below shows that the majority of consumers across all events had little to no familiarity with Lake County wines previous to the tasting event. This is not surprising given the smaller size of most wineries in Lake County and varying distribution reach of the wines.



The post event survey found that 66 percent of respondents identified themselves as “very familiar but with a few wineries” to “very familiar with the region, its sub-appellations and various wineries.” This is a dramatic increase over the pre-event results when just 13 percent of responses were similar. The post event survey audience consisted of 23 responses.



Results of post-event consumer surveys indicated that consumers felt they had added a little extra knowledge from their participation and increased their curiosity to try and learn more about Lake County wines.

Goal 2 - Partners will adopt or leverage the course material developed under this grant proposal. Partners and supporters for this project were invited to adopt or leverage course materials and the course website. Measure of success was written reports from partners with at least three partners agreeing to use the materials. This is a long-term goal. The website course was launched during the last month of the grant. Response from partners was very positive with five agreeing to use the materials and help publicize the website.

The County of Lake, the Lake County Chamber, Sonoma State University Wine Institute, Santa Rosa Junior College Wine Studies program, and the Lake County Winery Association have all agreed to adopt or leverage the materials on the website. The County of Lake plans to link the county visitor website to the course website and leverage the video content. The Lake County Chamber, overseer of the Lake County Certified Tourism Ambassador program, has agreed to include the website course as an option for Certified Tourism Ambassadors to earn points towards renewal of their annual certification. Executive Director of the Wine Business Institute at Sonoma State has agreed to offer the materials on the website as a resource to students. The instructor for Beginning Wine Chemistry, Santa Rosa Junior College summer program, requested course materials for use in his class. The Lake County Winery Association has helped to promote the new website in an email blast to their email list of 4,000 individuals. Individual winery members have agreed to promote the website to customers using rack cards.

Goal 3: Consumers, industry, media, and trade audiences will rate course material as good (4) or very good/excellent (5) on increased familiarity and awareness of Lake County wine and winegrapes. Performance measure: Responses to online surveys. Benchmark: None. Target: 70 percent will rate material as 4 or 5 on a 5-point scale for increased familiarity and awareness.

Under this grant, course material was created to reach consumer, trade and media, and sommelier audiences. The material was originally created as a PowerPoint presentation to be used for seminars to live audiences. It was also migrated to a website platform with extensive information about Lake County wine and winegrapes. The website was launched in early June 2018.

In-Person Course Presentation
The course material was presented to sommelier, trade and media audiences in live seminars/presentations at three outreach locations.

Seminars were held in New York City for media and trade. The combined survey response for these events indicated that 100 percent of the attendees rated the information and materials as a 4 or 5 for increasing familiarity and knowledge of Lake County wine and winegrapes.

New York City Media and Trade Presentations					
On a scale of 1 (poor) to 5 (excellent), please rate the usefulness of the information given, and the materials handed out, in the presentation					
	1 (poor)	**2**	**3**	**4**	**5 (excellent)**
Increasing my awareness of Lake County varieties and wines	0%	0%	0%	11%	89%
Increasing my familiarity and knowledge about Lake County	0%	0%	0%	11%	89%
I can present and explain Lake County wines to my customers	0%	0%	0%	33%	67%

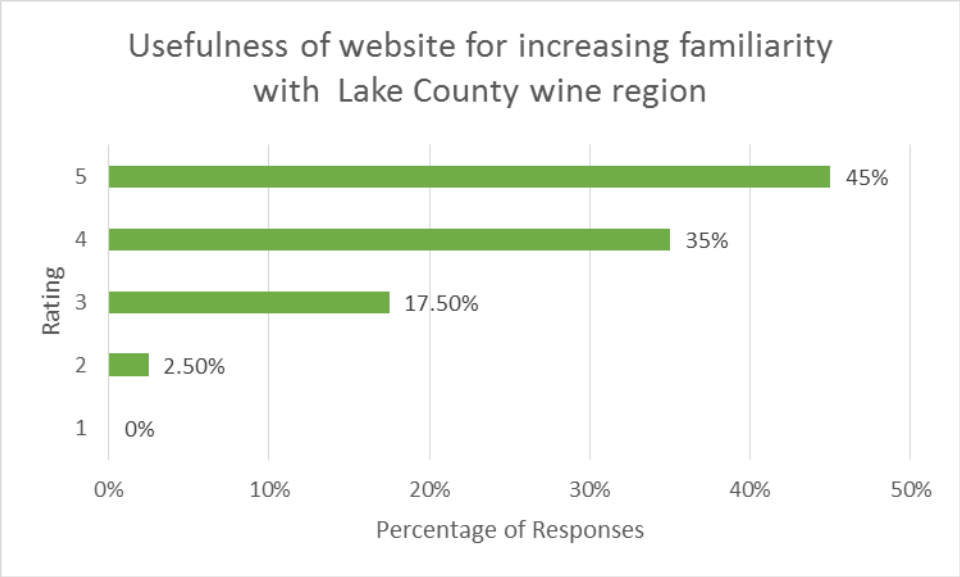
At TEXSOM, 95 percent of the responses rated the seminar as a 4 or 5 on a 5-point scale for increasing awareness and 94 percent rated the seminar as a 4 or 5 in increasing familiarity and knowledge of Lake County wine and winegrapes.

Lake County TEXSOM TRADE Lunch Seminar					
On a scale from 1 (poor) to 5 (excellent), please rate the usefulness of your experience at the TexSom Lake County lunch seminar.					
	1 (poor)	2	3	4	5 (excellent)
Increasing my awareness of Lake County varieties and wines	0%	0%	5%	15%	79%
Increasing my familiarity and knowledge about Lake County wines	0%	3%	3%	26%	69%
Increasing my curiosity in finding and learning about more Lake County wines	0%	0%	8%	15%	77%
I can now present and explain Lake County wines to my customers more effectively	0%	3%	21%	26%	51%

The seminar was also presented at Somm Con in San Diego in November 2017. One-hundred percent of the post course survey respondents rated the usefulness of material on increased familiarity and awareness of Lake County wine and winegrapes as a 4 or 5 on a 5-point scale.

Somm Con Lake County Seminar					
On a scale from 1 (poor) to 5 (excellent), please rate the usefulness of your experience at the Somm Con Lake County seminar.					
	1 (poor)	2	3	4	5 (excellent)
Increasing my familiarity and knowledge about Lake County wines	0%	0%	0%	17%	83%
Increasing my curiosity in learning about and finding more Lake County wines	0%	0%	0%	17%	83%
I can now present and explain Lake County wines to my customers more effectively	0%	0%	0%	50%	50%

Course Website
An on-line survey for the website course was used to measure the usefulness of the material as well. Forty responses were received for this survey. Eight-two percent of the survey respondents were consumers with the remaining 18 percent being from the trade. Eighty percent of the respondents rated the usefulness of the website material as a 4 or 5 on a 5-point scale for increased familiarity and awareness.



These results demonstrate that the goal 3 was exceeded for both in-person presentation and on-line format.

Goal 4: Average return per ton over three-year cycle (2014-2016) for Lake County winegrapes will increase by $50 per ton by 2016. Performance measure: Average return per ton for three-year cycle 2014-2016 for Lake County based on figures from annual California Grape Crush Report.

Benchmark: Average return per ton for the three-year cycle of 2011-2013. Target: $50 per ton average price increase over the three-year period from 2014 through 2016. This goal was exceeded. Average return per ton for the three-year cycle of 2014 – 2016 was $1,596.02, an average increase of $268 per ton based on the California Grape Crush Report. This trend continued in 2017 with an average return of $1,751.43 per ton.

Baseline data for Goal 4

Variety	2011	2012	2013	Cumulative Average Returns 2011-13	Average Returns Per Ton 2011-13
Total Whites	$936.55	$1,052.16	$1,087.79	$3,076.50	$1,025.50
Total Reds	$1,335.09	$1,559.68	$1,627.75	$4,522.52	$1,507.51
Total All Varieties	**$1,191.97**	**$1,384.60**	**$1,407.49**	**$3,984.06**	**$1,328.02**

Final data for Goal 4

Variety	2014	2015	2016	Cumulative Average Returns 2014-16	Average Returns Per Ton 2014-16
Total Whites	$1,115.75	$1,140.99	$1,171.04	$3,427.78	$1,142.59
Total Reds	$1,822.20	$1,921.39	$2,120.65	$5,864.24	$1,954.75
Total All Varieties	**$1,517.60**	**$1,588.60**	**$1,681.87**	**$4,788.07**	**$1,596.02**

Major successful outcomes for this project include:

- An increase of $268 average return per ton for Lake County winegrapes over the three-year cycle of 2013 – 2016;
- Creation of a course on the Lake County wine region for both seminar presentation and on-line access;
- In-person and on-line course delivery, directly reaching over 800 participants;
- Pouring Lake County wine and educating participants about Lake County wine and winegrapes at trade and consumer tastings in four geographic locations that attracted over 14,500 people;
- Advertising with more than 16,000,000 impressions.

Beneficiaries

This project benefitted members of the Lake County wine industry including winegrape growers and wineries by continuing to promote Lake County wine and winegrapes to key audiences and markets and increased their knowledge and access to messages and resources for their individual businesses. Entities that provide support services to the Lake County wine industry such as farm labor contractors, material suppliers, and wine/winegrape brokers indirectly benefited from grant activities due to the improvement in the demand for Lake County winegrapes and wine.

This project benefitted members of the Lake County wine industry including an estimated 180 growers, 32 Lake County wineries as well as an estimated 25 wineries located outside Lake County who bottle wines under their own label and identify with a Lake County appellation as well as tourism businesses, lodging partners, hospitality providers, and Lake County Certified Tourism Ambassadors.

Lessons Learned

- Need for continued marketing of Lake County wine and winegrapes: This project expanded the key messages developed under the previous project, Lake County Rising and targeted outreach to key stakeholders with enhanced emphasis on sommeliers and trade. Survey results from this project were positive, especially in terms of future interest in the region's wine. That said, the project again reinforced the notion that continued marketing is a critical need for future growth and financial success in the region. Grant activities focused on both industry and consumer segments with more emphasis on reaching sommeliers, media, and other trade members.
- Pouring opportunities for Lake County wines: As an advertiser in Wine Spectator, Lake County was invited to pour wines at events in Chicago and New York City with no charge for participating. These events reached a larger consumer audience in both markets.

- Using other specialty crops in food and wine pairing: When this grant was written, it was envisioned that other specialty crop food items could be used at outreach events for use in food pairings. This proved to be more challenging and expensive than anticipated with the myriad of regulations for food service and requirements in many locations to use specific food providers well over the grant budget.
- Survey measurement: Surveys played a key role in the measurement process. The wording of survey questions was varied between locations and audiences. This approach secured some interesting qualitative data about Lake County wine and markets, although in some cases, it resulted in some less than perfect data from which to draw conclusions.
- Using pre-event surveys to measure effectiveness of outreach events for consumers required some adjustment to the usual process. Survey cards with just one question were created to measure familiarity with Lake County wines and winegrapes at these events. The success of this approach was dependent on brand ambassadors consistently asking participants to complete the survey. It had limited success when venues were busy and ambassadors were engaging customers in conversation to provide information about the wine and wine region.
- Incentives were offered for all post-event surveys. Respondents were offered a chance to win the book 'Volcanic Wines: Salt, Grit and Power,' plus a basket of Lake County goodies. This was an in-kind contribution by LCWC and increased survey participation as well as provided additional information and key messages about Lake County wine and winegrapes to the winner.
- Anecdotal comments and observations from surveys provided some interesting and positive results.
  1. Trade surveys showed most respondents retained each of the key facts about Lake County presented in the seminar. Eighty to ninety percent correctly recalled the roles of UV light, volcanic soils, and diurnal temperature swings.
  2. Consumers felt they had added a little extra knowledge from the events; but the greater impact was on curiosity to try and learn more about Lake County wines.
  3. Website visitor comments included: well done; informative and easy to use; great job putting Lake County wines on a "wine list"; engaging website; something for everyone from the casual web cruiser to the person who wishes to delve deeper.

Unexpected outcomes include:

- Outreach event locations: The locations for outreach events were revised during the execution of the grant based on advice from the CCOEC and key stakeholders as well as expanded focus on reaching the sommelier audience. This resulted in more effective outreach events in major markets and expanded the relationship for LCWC with two major sommelier events, with opportunities to make expanded presentations about Lake County at both events and future invitations to return.
- Change in format for on-line course: The original project plan included conversion of the course material to on-line format using Articulate Storyline software. Meetings were held with stakeholders in the Lake County wine industry in the summer of year two, after two outreach events had been completed using the course material. Stakeholders expressed strong desire to ensure that the course had a vivid visual impact to express the beauty of the area and draw in the visitor to learn more. This resulted in a decision to create the educational course as a stand-alone website. Although it took longer than originally planned, the website offers a rich source of information to educate key audiences far into the future.
- Including a Project Manager for the grant: The original grant plan did not include a Project Manager (PM). Both the Project Director and main Project Partner organizations have limited staff to carry out

grant activities as well as normal operations. A PM contractor was added during the execution of the grant to ensure timely performance of project activities.

- Timeframe for grant activities: This project had a timeframe of 30 months. Due to the impact of the Valley Fire, which hit in September 2015, major activities were not underway until a year into the grant, with actual activities completed over 24 months. The lesson learned was that grant activities could have been (and were) completed in a shorter timeframe.

Additional Information

The following additional information is available at:
https://drive.google.com/drive/folders/1aKh1UE0rGGTlOFdNqslrUzmgAVOt86bK?usp=sharing

Course Materials and Reports
PowerPoint Presentations
Website: www.lakecountywine.org
Drone Videos: www.lakecountywine.org/terroir/appellations/
Lake County Market Mapping

Photographs
New York City events
Aspen Food and Wine Festival
TEXSOM
SommCon
San Diego Wine and Food Festival
Chicago LuxeHome Chill event
International Volcanic Wines Conference

Advertising Copy
Wine Enthusiast Advertorial
Wine Enthusiast full page ads
Wine Spectator ads
Food and Wine Magazine ad
The Tasting Panel Magazine ad
The SOMM Journal Magazine ad

Printed Materials
Rack Card for events
Rack Card for website course
Coaster Design

Media Articles:
"Shining a Light on Lake County," *The Tasting Panel* Magazine, June 2018
"Gaining Ground," *The SOMM Journal*, June 2018
"The Lake County Eruption," *The SOMM Journal*, October/November 2017
"The Savvy Lake," Alder Yarrow, May 2018
"Lake County Capitalizes on Volcanic Wines," *Wines and Vines*, March 2017

USDA Project No.: 8	Project Title: Forecast of Pistachio Crop Yield Using Predictive Machine Learning Modeling	
Grant Recipient: California State University, Fresno	**Grant Agreement No.:** SCB15008	**Date Submitted:** December 2018
Recipient Contact: Shawn Ashkan	**Telephone:** (559) 278-8652	**Email:** sashkan@csufresno.edu

Project Summary

Pistachio is a valuable crop in California's San Joaquin Valley, covering more than 320,000 acres with an annual revenue of over $1 billion. To compete in the international market, the pistachio industry will need to make good predictions of harvest yields early in the crop season for planning harvest resources, pricing, budgeting, storage, and export decisions. Pistachio yield prediction has been a topic of interest for producers, and the industry has demanded accurate and timely early season forecasts of crop yields. Yet, at the time, there were no established method for predicting pistachio yields early in the crop season. This project addressed the demand by investigating pistachio crop yield prediction models using machine learning principles.

Accurate and timely pistachio yield predictions are essential for harvest planning, marketing, and exporting decisions made by the large pistachio industry in California. Pistachio has certain chilling requirements during the winter dormancy, and warmer winters due to climate change may affect the crop yield performance in the San Joaquin Valley. Pistachio also has strong alternate bearing behavior, which complicates the forecasting. Pistachio crop yield was primarily estimated by costly and time-consuming subjective grower interviews and objective field surveys. This project addressed the need to develop accurate pistachio crop prediction models using weather and agronomic data.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The activities performed during the grant period were as follows: collection of weather and yield data in all major pistachio-growing counties in California (Fresno, Kern, Tulare, Kings, Madera, and Merced), analysis of the data, preparation of predictive machine learning models, and publication of the final model online for pistachio growers and industry applications.

Weather Data:
All available relevant hourly weather data (air temperature, relative humidity, and wind speed) in the major pistachio growing areas in the San Joaquin Valley were collected and analyzed in this project. The following weather stations were used (Figure 1):

- California Irrigation Management Information System (CIMIS) weather data, 25 automated weather stations managed by the California Department of Water Resources.
- National Weather Service airport and city data from Fresno, Bakersfield, Porterville, Lemoore, Hanford, Visalia, and Madera stations.
- Local stations temperature data from University of California Integrated Pest Management Program.

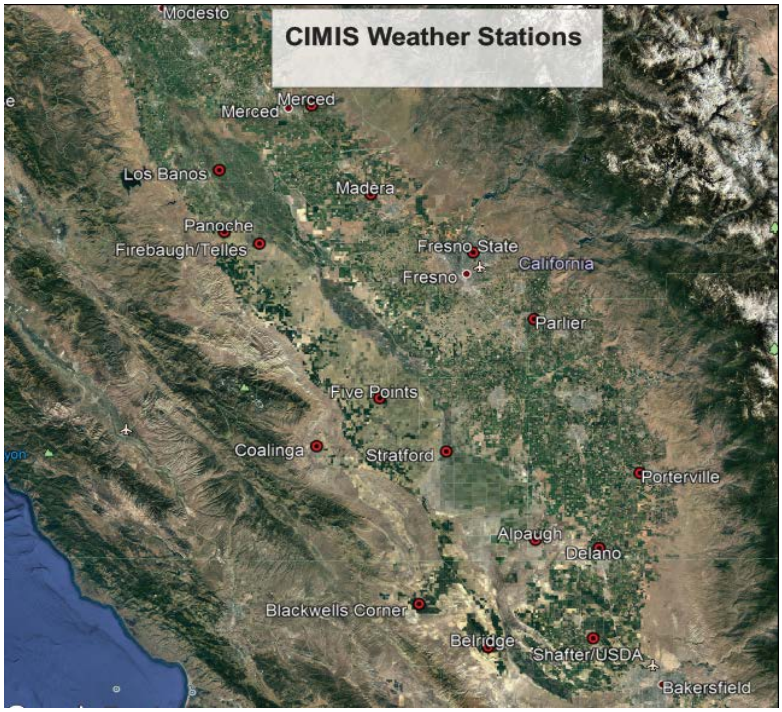


Figure 1. California Irrigation Management Information System weather stations in the San Joaquin Valley

The hourly data were quality controlled for missing data and out of range values. The gaps were filled with the data from neighboring stations. After analyzing and comparing the data from various sources for representativeness, consistency and adequacy, it was decided to use the weather data from only CIMIS weather stations in this study.

Air temperature during the winter dormancy were the main variables in this project. Wind speed and relative humidity were less important variables for this study. Various chilling model and air temperature-derived variables were investigated to determine the adequacy of pistachio winter chill and spring heat in the San Joaquin Valley. Winter chill was calculated using Chilling Hours Model, Utah Model, Dynamic Model, and Temperature (Ta) accumulation. Spring heat was calculated using Growing Degree Hours, and Growing Degree Days. A brief explanation and sample graph for each method can be found below for the CIMIS station #80, Fresno State, one of the CIMIS stations in the San Joaquin Valley:

Table 1: Chill units to different temperature ranges:

Air Temperature (ºC)	<1.4	1.5-2.4	2.5-9.1	9.2-12.4	12.5-15.9	16-18	>18
Chill Units	0	0.5	1	0.5	0	-0.5	-1

The Chilling Hours Model gave the number of hours (chilling hours) that the hourly temperatures fell between 0 and 7.2 degrees Celsius during the winter dormancy (Figure 2). The Utah Model, assigned different chill units to different temperature ranges (Table 1 and Figure 3). The Dynamic Model was used to calculate chill portions in a two-step process to account for warm temperatures that occurred during the winter dormancy. The calculation procedure of this model was more complicated than other models. More information can be found at: http://fruitsandnuts.ucdavis.edu/Weather_Services/chilling_accumulation_models/ (Figure 4 and 5).

The Temperature Accumulation Model gave hourly air temperature accumulation below 4.5 degrees Celsius for different time periods during the dormancy period (Figure 6). The Growing Degree Hours method calculated heat accumulation using a base temperature (4.5 degrees Celsius) and an upper/cutoff temperature (25 degrees Celsius) (Figure 7). Lastly, the Growing Degree Days method used daily maximum and minimum air temperatures to calculate Growing Degree Days. The base temperature for crop development and the upper temperature for crop development increases were 4.5 and 25 degrees Celsius, respectively (Figure 8).

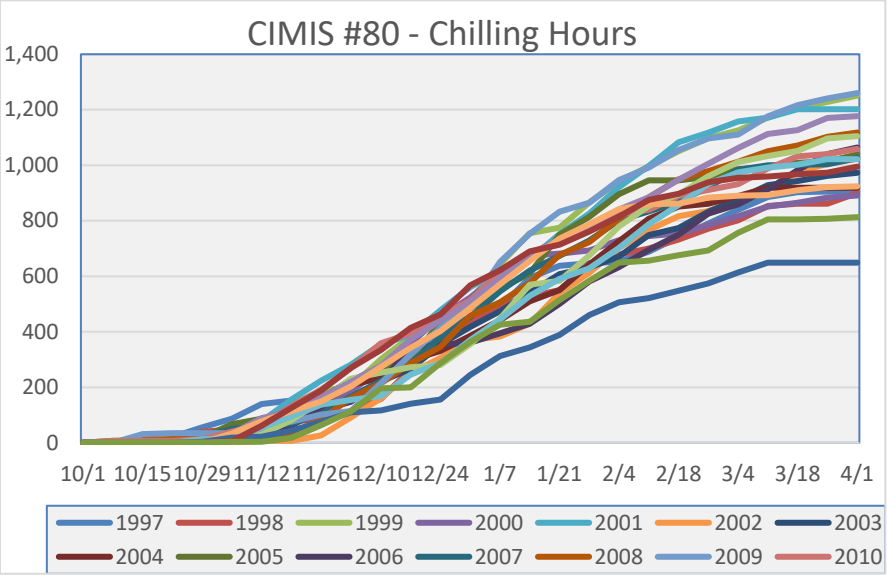


Figure 2. Chilling Hours from California Irrigation Management Information System, (CIMIS) Station #80, Fresno State.

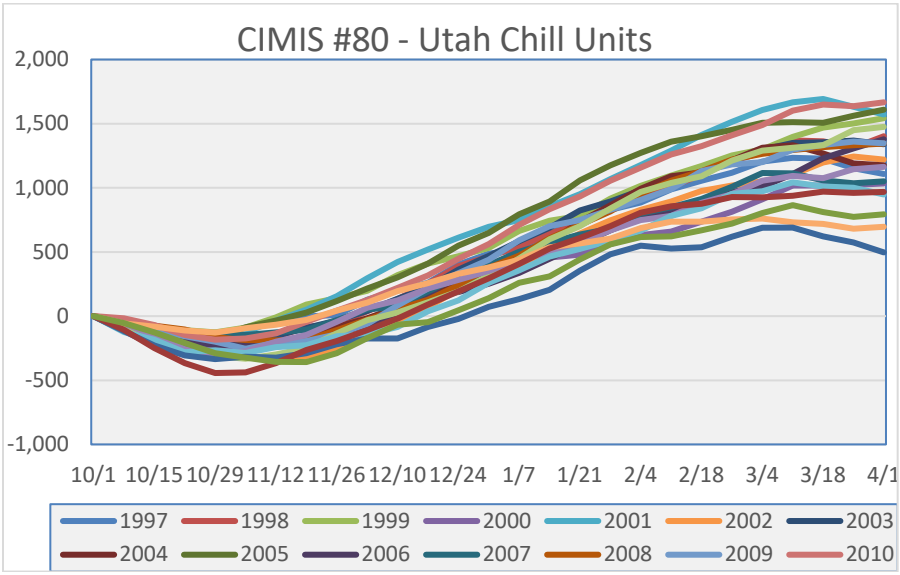


Figure 3. Utah Chill Units from California Irrigation Management Information System, (CIMIS) Station #80, Fresno State.

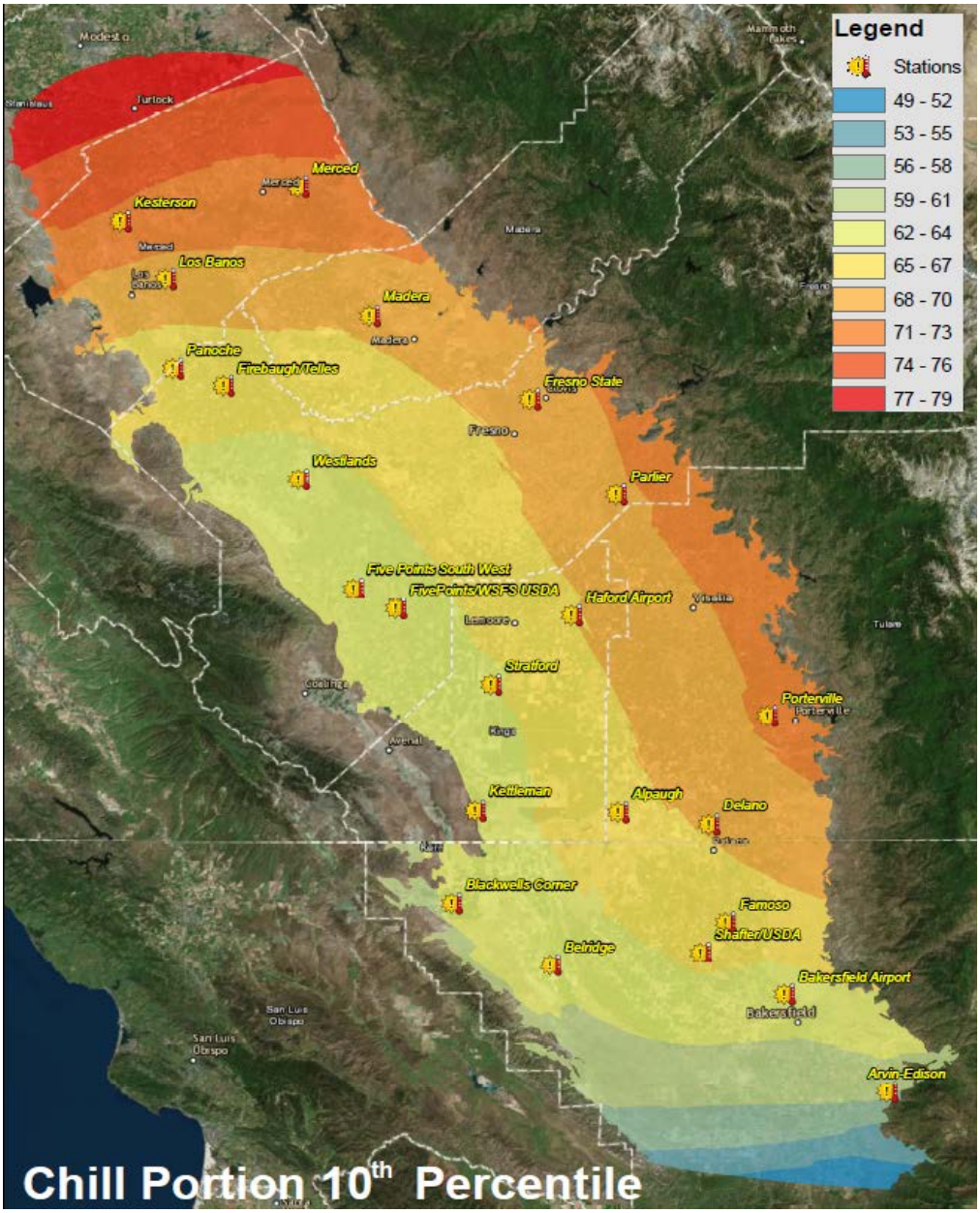


Figure 4. Seasonal (Fall &Winter) Dynamic Model Chill Portion in the San Joaquin Valley.

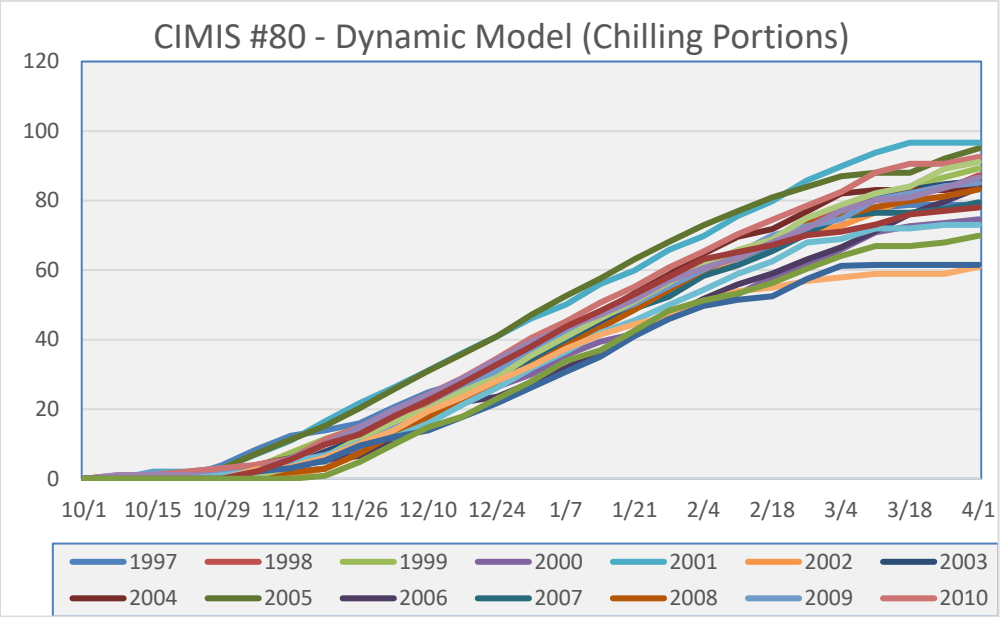


Figure 5. Dynamic Model from California Irrigation Management Information System, (CIMIS) Station #80, Fresno State.

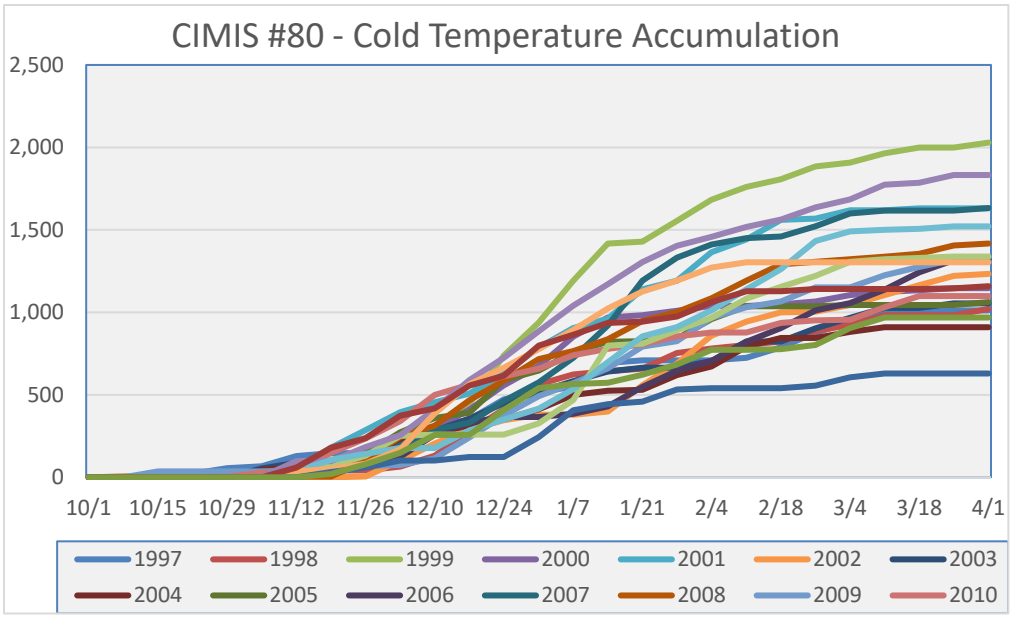


Figure 6. Cold Temperature Accumulation from California Irrigation Management Information System, (CIMIS) Station #80, Fresno State.

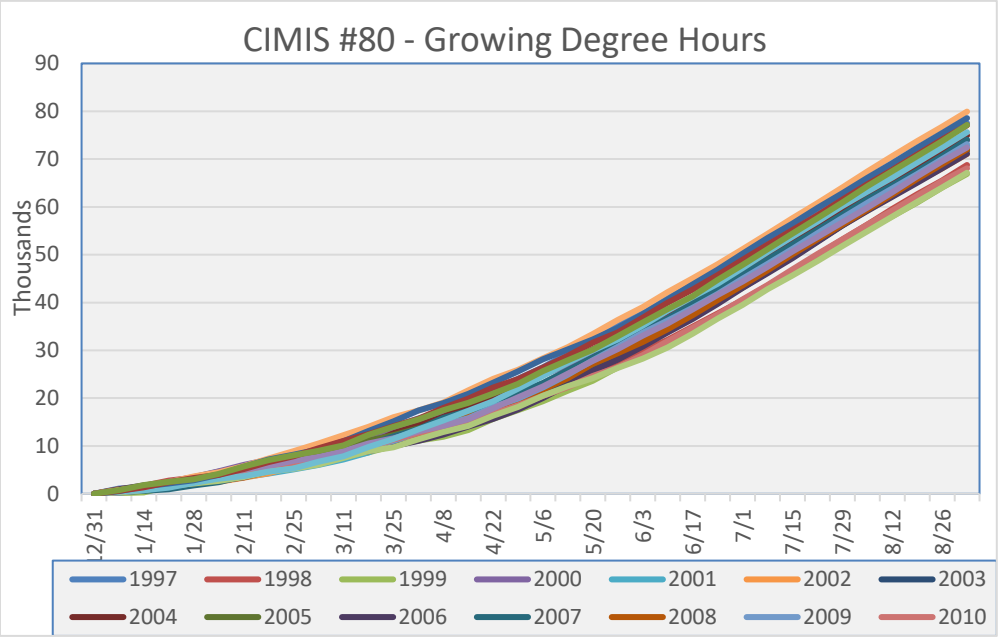


Figure 7. Growing Degree Hours from California Irrigation Management Information System, (CIMIS) Station #80, Fresno State.

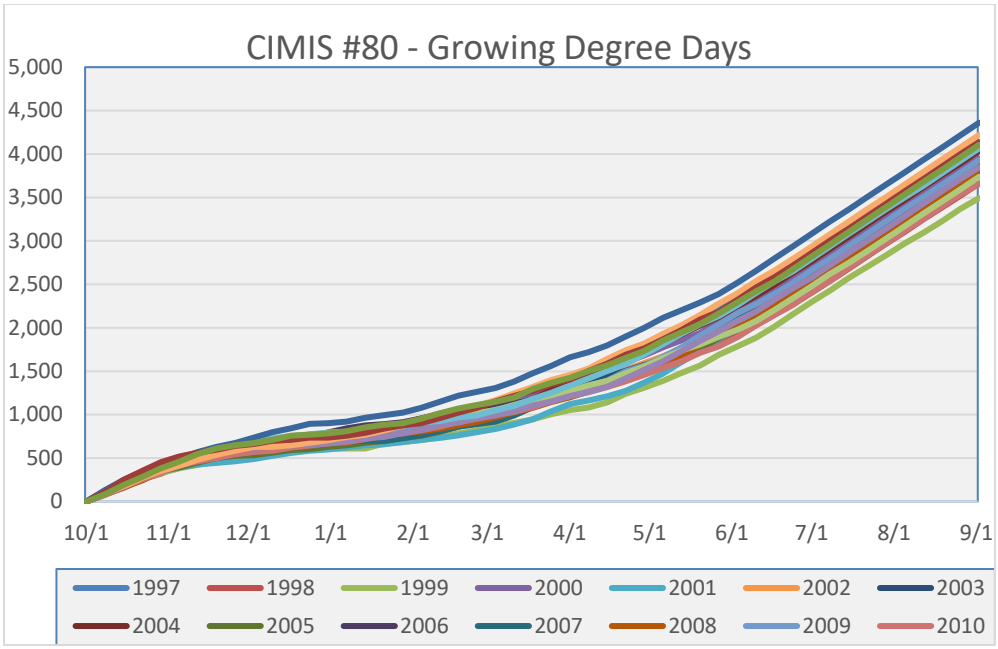


Figure 8. Growing Degree Days from California Irrigation Management Information System, (CIMIS) Station #80, Fresno State.

The above-mentioned models were prepared and employed in this study. Additionally, the following air temperature data ranges were also calculated and analyzed:

- The number of hours for air temperatures less than certain values, from 0 to 30 degrees Celsius for different time periods from October 1 to June 1 of the next year for every 15 days. For example, the number of hours temperatures were less than or equal to four from November 1 to January 15, or the number of hours temperature was less than or equal to seven from November 15 to April 15. There were over 4,000 different data points in this category.
- The number of hours for air temperatures greater than certain values, from 0 to 30 degrees Celsius for different time periods from October 1 to June 1 of the next year for every 15 days. For example, the number of hours temperature were greater than or equal to 16 from October 15 to February 15, or the number of hours temperatures were greater than or equal to 25 from March 15 to April 15. There were over 4,000 different data points in this category.
- The number of hours for air temperatures between less than certain values (0 to 10 degrees Celsius) minus air temperature greater than certain values (10 to 30 degrees Celsius) for the same time periods. For example, the number of hours for temperatures less than or equal to three from November 15 to April 15, minus the number of hours temperatures were greater than or equal to 26 from November 15 to April 15. Or, the number of hours temperatures were less than or equal to two from October 15 to May 15, minus the number of hours temperatures were greater than or equal to 20 from October 15 to May 15. A large database with over 30,000 data points. The purpose of this database was to test the likely negative impact of high temperature during the different periods of pistachio dormancy time.

Yield Data:
The original objective of this research project was to develop a technique to learn the relationships between pistachio crop yield and related variables from industry diverse empirical datasets using machine learning algorithms. The project was originally planned to investigate the effects of the needed dormancy temperatures and other agronomic conditions and cultural practices (e.g., cultivar, pest control, pruning, nitrogen and water applications) influencing the crop yield at the field/block level. The plan was to compile and analyze thousands of historical field data points and agronomic and environmental conditions along with cultural practices to predict the crop yields early in the season by June for industry planning purposes. Unfortunately, the crop yield data at the field level could not be obtained from growers as planned due to privacy concerns. Some growers, however, kindly provided their field data which were used for predictive modeling. More than 500 yield data points were received from different growers. For consistency, only data from orchards with more than seven years of age were used in the modeling, 406 field/block yield data total. The growers' yield data were obtained through the University of California nut crop farm advisors, and the project co-investigator.

In addition to growers' data, published county-level yield data for all major pistachio growing counties (Fresno, Kern, Tulare, Kings, Madera, and Merced) for the period 1996 to 2017 were collected and analyzed as well. Pistachio is an alternating crop, giving 'high' yield followed by 'low' yield due to the crop genetic codes. The historical yield data in different counties of the San Joaquin Valley showed that crop yields were somehow synchronized with the weather conditions (i.e., valley wide good crop year/bad crop year), indicating that the winter dormancy temperature regime could somehow heavily outperform the crop alternate

'on' and 'off' years at the field level. This could make predicting the pistachio yield early in the crop season challenging.

Machine Learning Modeling:
The main purpose of modeling in this project was to make a prediction, not to test a hypothesis. In this modeling, air temperature ranges or air temperature-derived variables were taken as independent or predictor variables and current crop yield as dependent or outcome variables. The objective was to see how these air temperature ranges or temperature-derived variables contributed to pistachio yield. Even though pistachio was genetically a strong alternating crop, there was a weak relationship between the current and previous crop yields for the data used in this project. This relationship was not improved much when previous yields were squared or cubed. This indicated that other factors such as air temperature regime during the fall/winter, agronomic conditions (water and nitrogen applications and pruning practices) could play a dominant role concerning the crop yield.

Microsoft® cloud-based Azure® Machine Learning Studio was used as a research tool to create and evaluate models to predict pistachio yields. The software had many built-in algorithms with selection variables and could handle large datasets at high speed (Figure 9). The available pistachio crop yield data may not perfectly represent the entire population; therefore, the data was randomly split into two sets: a training set (75 percent) and a testing set (25 percent) to avoid overfitting the prediction. An experienced machine learning modeling engineer helped the principal investigator with machine learning and statistical analysis in this project.

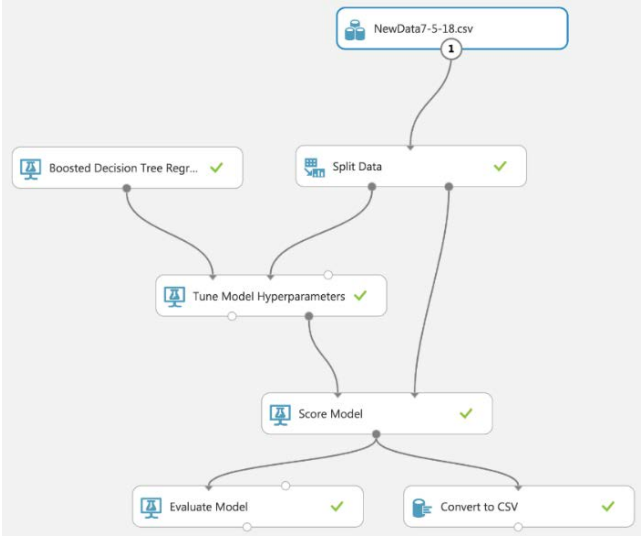


Figure 9. Sample machine learning model

Various regression models (linear regression, Poisson regression, Bayesian linear regression, boosted decision tree regression, and neural network regression) were tested and evaluated for suitability (as compared by coefficient of determination, mean absolute error, root mean squared error, relative absolute error, and relative squared error). Numerous trials were conducted with different regression models and weather features to find suitable results for pistachio crop yield prediction. The objective was to find a combination of best machine learning algorithms and features to estimate crop yield while reducing the size of the feature set to simplify the model application.

In addition to machine learning modeling, the SPSS® IBM statistical software program was also used to provide basic statistics and properties of various datasets, examine various linear regression methods (stepwise, forward, backward), and to perform normality and collinearity diagnostics.

Model Publication:
The main goal of this project was to develop a timely and cost-effective prediction tool to help pistachio growers and the industry to better manage harvest, storage, and market decisions. Results of the machine learning modeling were published online (Pistachio Predictor: http://pistachio.azurewebsites.net/) for growers and industry applications. The Pistachio Predictor can be accessed on mobile devices as well. The Pistachio Predictor has been introduced to the manager of the California Pistachio Research Board (the Board) along with background information.

The Pistachio Predictor was based on dormancy (fall-winter) chilling portions. Pistachio growers and the industry were quite familiar with the subject and understood the concept. The online tool was created to be very simple, easy to use, and did not require users to collect any chilling portion data. Users could freely access the software program, have their own yield data for the current year or past years. The online Pistachio Predictor had live links for the required chilling portion data, which was made available from the University of California Fruit & Nut Research and Information Center (http://fruitsandnuts.ucdavis.edu/Weather_Services/chilling_accumulation_models/Chill_Calculators/index.cfm?type=portion). An instructional walk-through video was also included with the online Pistachio Predictor. To date, the site has been accessed 918 times. The online tool will be maintained by the California State University, Fresno moving forward.

This project solely covered pistachio trees, and all the funds spent, and activities conducted were entirely for predicting pistachio crop yields. Expenditures were tracked to further ensure that all grant fund were used to solely enhance the competitiveness of specialty crops.

This project involved collection of historical crop yield and quality data from growers throughout the San Joaquin Valley for machine learning modeling. Therefore, the project involved pistachio growers and processors and the Board, particularly the manager of the Board. All the basic data and information regarding the locations and extents of farms for historical data collection were gathered and mapped in partnership with the manager of the Board. Farm advisors in Fresno and Madera counties (University of California Cooperative Extension) helped with yield data collection. Adequate collection of historical pistachio crop yields data and information would not have been possible without contributions by the project partners.

Goals and Outcomes Achieved

The performance measure of the project was the actual (published/reported) pistachio crop yield, and the modeled predicted yield compared to the actual yield. The measurable outcomes of the project were 1) improved knowledge and better understanding of how winter chill conditions affect pistachio crop yields, and 2) improved early season pistachio yield forecasting that will result in better harvesting plans, better utilization of harvest equipment and storage facilities, and better pricing and marketing decisions.

The activities completed to achieve the performance goal and measurable outcomes included compilation, cleaning, and analyzation of the historical weather and crop data. Discussions on crop yield were held with experienced growers and farm advisors. Other activities included, preparation of features for modeling, the

running of countless machine learning models, and analyzation of the statistical variables. Preparation of the final model and launch of the application program (Pistachio Predictor) with instructional video for California growers was also carried out.

The outcome measures of the project were not long term. The main goals of the project were to prepare a model and launch a dedicated website to predict pistachio yield for the upcoming crop year, which were accomplished. These goals enhanced the crop yield forecasting knowledge and capability of the pistachio industry. However, the model Pistachio Predictor was developed using fewer historical crop yield data than originally planned.

Currently, the pistachio growers in California do not have any yield prediction tools available at their disposal. Personal communication was held with several University of California farm advisors and specialists, as well as pistachio growers. These conversations suggested that most farmers either used visual observations based on their experience to predict yield or they used yield numbers from previous years to have an estimate. Therefore, there was no baseline data for pistachio yield prediction as there were no science-based or data-based tools available for prediction/estimation of yield and there was a need for developing such tools. The Pistachio Predictor developed in this project was made available online for pistachio growers and the related industry.

The overall objective of this project was achieved successfully (i.e., developing a timely and cost-effective prediction tool for pistachio growers). The research product was a validated pistachio's machine-learning crop yield prediction model for the major pistachio production counties in the San Joaquin Valley (Kern, Fresno, Madera, Tulare, and Kings) based on the readily available weather data. The graph below shows how the Pistachio Predictor approximated the published yields by the 'Administrative Committee for Pistachios (ACP)' in the last 14 years in the San Joaquin Valley (Figure 10 and Table 2).

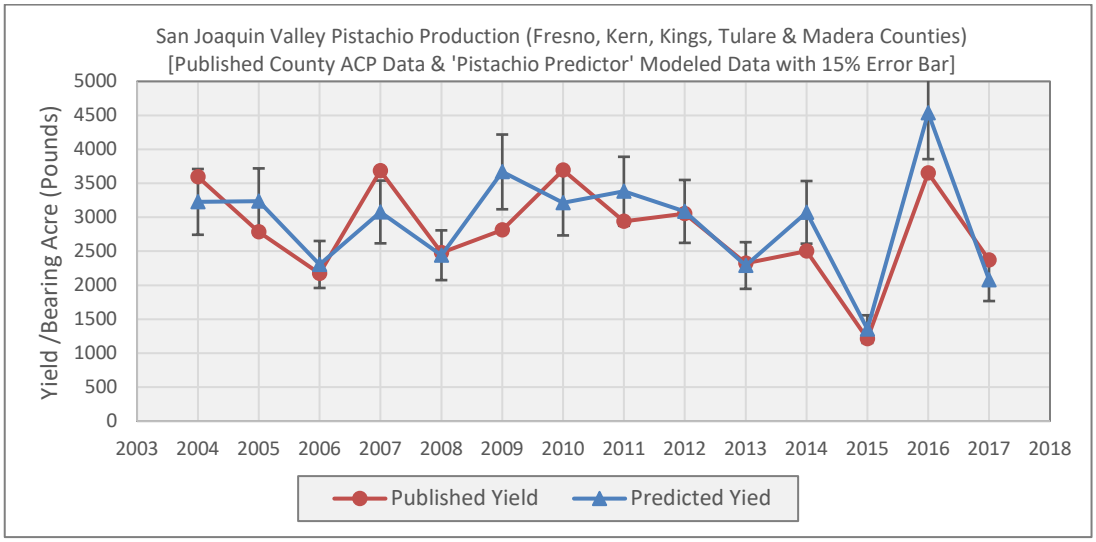


Figure 10. The approximated published yields versus predicted yield made by the Pistachio Predictor.

Table 2. San Joaquin Valley Production (Fresno, Kern, Kings, Tulare, and Madera Counties) and Pistachio Predictor Yield Data.

Year	Published Yield	Predicted Yield	Percent Error
2017	2370	2079	-12%
2016	3653	4536	24%
2015	1211	1354	12%
2014	2501	3073	23%
2013	2324	2290	-1%
2012	3051	3086	1%
2011	2940	3383	15%
2010	3694	3215	-13%
2009	2813	3668	30%
2008	2476	2441	-1%
2007	3686	3078	-17%
2006	2173	2305	6%
2005	2783	3234	16%
2004	3596	3227	-10%
Average			**5%**

This project resulted in the creation of the Pistachio Predictor, which was a dedicated pistachio yield-forecasting website, http://pistachio.azurewebsites.net/. The website was shared with pistachio growers and other stakeholders through the California Pistachio Research Board. Also, the website was introduced via several newspaper and newsmagazine publications.

The information on how to get to the Pistachio Predictor website and how to use the calculator was shared with pistachio growers at various growers' meetings such as the California Statewide Pistachio Day, California Pistachio Research Board meeting, University of California Cooperative Extension Farm Advisors, and also via direct personal communication with growers.

Beneficiaries

Pistachio growers were the main beneficiary of this project. Other related operations such as pistachio processing, harvesting, storage, and marketing benefited from this project as well. Approximately 1,200 pistachio beneficiaries benefitted from the project.

Lessons Learned

The original plan of the project was to collect industry-wide historical yield data from a large number of growers along with field agronomic conditions (e.g., fertilizer and water applications, pruning practices) for modeling with weather and environmental variables. The plan was discussed with the Board in the first year of the project study and the manager of the Board welcomed the idea and prepared the required maps of designated pistachio orchards (based on the project weather stations map) and discussed the matter with the orchard owners. Some big owners expressed concerns about privacy of the data and were not willing to provide their historical yield data despite the presented plans of data safeguarding. Therefore, large industry-

wide yield data were not collected as desired. More dialogue will be needed with growers about the importance of their data to conduct research and provide tools and more knowledge for the industry.

Additional Information

No additional information.

USDA Project No.: 9	Project Title: Improved Post-Storage Walnut Quality by Understanding Water Activity Relationships	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SBC15009	**Date Submitted:** December 2018
Recipient Contact: Elizabeth Mitcham	**Telephone:** (530) 304-1259	**Email:** ejmitcham@ucdavis.edu

Project Summary

Consumers and health professionals recognize the benefits of consuming nuts, but walnuts are a unique nut in that they contain the highest amount of alpha-linolenic acid and a 4 to 1 ratio of linolenic acid to alpha-linolenic acid. However, the polyunsaturated fatty acids that make walnuts an attractive health choice also make them prone to oxidation during storage leading to rancidity of the oils. Development of rancidity throughout storage and marketing shortens shelf life, restricts consumer demand, and leads to hesitancy of product developers to include walnuts as an ingredient, thus limiting the market reach of the California walnut industry. Quality issues also include undesirable textural changes, development of mold, and kernel darkening, as well as rancidity, and frequently cause nuts to be rejected by buyers due to the high-quality standards of both international and domestic markets.

California is the sole producer of walnuts in the United States. As walnuts are harvested in the fall and continuously stored and shipped throughout the year, walnut quality must be maintained for at least 12 months. Due to the increases in production and yield for walnuts, storage times might increase. Understanding how storage conditions impact quality over time is imperative for the California walnut industry to successfully manage these increases in production, grow market opportunities, and minimize losses.

This project's goal was to seek understanding of how the rate of deterioration of walnut quality (rancidity development, kernel darkening, and mold development) was affected by storage conditions (relative humidity and temperature) for different walnut varieties and harvest times, and stored in shell or as kernels. Water activity, or the amount of free water in a sample available to support metabolic activity, is related to the relative humidity of the storage conditions. Product stored at a higher relative humidity will have a higher water activity because there is more moisture in the air and as the product equilibrates, it retains the moisture within its tissues. Water activity has been said to be directly related to the rate of deterioration in a food; however, this rate of deterioration with walnuts was not previously established.

The initial objectives of this project were to: 1) Establish the relationship between walnut moisture content and water activity and determine how it is influenced by storage conditions; 2) Determine the effects of temperature and relative humidity on the rate of quality loss (rancidity, kernel color, taste) of each variety during storage; 3) Recommend optimal storage conditions to reduce the rate of quality deterioration tailored to variety and harvest time; and 4) Establish water activity as a standard measure used by walnut storage operators to optimize post-storage quality.

This project is extremely timely and of great interest from the California walnut industry. Walnut acreage has increased substantially in recent years from 216,000 acres in 2006 to 300,000 acres in 2015. This increase in acreage combined with a 25 percent increase in yield per acre has led to a concomitant increase in total

production from 346,000 tons in 2006 to 603,000 tons in 2015. The walnut industry now has more acreage in production with a higher yield per acre, but is dealing with lower prices per ton and an overall decrease in crop value in recent years. This results in more product in storage for longer periods of time. The walnut industry must reduce the rate of quality deterioration in storage and develop new products and markets for walnuts. However, because of the limited shelf life of walnuts, their potential use in snack foods is limited. In a crop with total value of $976 million in 2015 with export value of $1.48 billion, minimizing postharvest losses and quality degradation by optimizing storage conditions is imperative to the success of an integral component of the California agricultural sector.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

To assess the currently utilized storage practices for the walnut industry, surveys were distributed to walnut processors with assistance from the California Walnut Board Grades and Standards Committee. Surveys were designed to form a baseline of knowledge of storage practices and quality issues experienced. Although the expected measurable outcomes initially stated that the target was to survey those responsible for 80 percent of the crop in California, the response rate accounted for only 30 percent of California walnut production. Due to the expanding nature of the walnut industry, there are now a greater number of smaller processors instead of a few larger ones. We believe this changing nature of the industry could account for the reason a lower percentage of the crop was represented in the survey despite reaching out to multiple processors.

The survey results indicated that temperatures during storage of in-shell walnuts range from 34° to 77°F, but many are held at ambient temperatures. Most kernels are stored in refrigerated conditions (40° to 65°F) but most operators do not control relative humidity. Survey respondents indicated problems with darkening of kernels (31 percent) and rancidity (40 percent) in in-shell walnuts. For kernel storage, 44 percent indicated issues with kernel darkening and 39 percent had problems with rancidity development.

In October 2015, walnuts of four varieties (Chandler, Howard, Tulare, and Vina) were obtained from Diamond of California. Each variety included an early and late harvest and walnuts that were in shell and cracked out into kernels. Prior to storage, an initial analysis was completed to assess the moisture content, water activity, kernel color, mold development, and oxidation levels at harvest. Storage conditions were established to include relative humidity of 20 percent, 40 percent, and 60 percent each at 41°F, 59°F, and 77°F. Including the variety, storage type (in shell or kernel), harvest, and relative humidity/temperature combination, 144 different combinations of experiment factors were included. These walnuts were placed into storage and quality was analyzed every three months. Data was compiled and organized after each three-month analysis.

In September 2016, the project was set up again but this time to include relative humidity of 40 percent, 60 percent, and 80 percent to more accurately reflect the survey results which had indicated that storage operators do not manage relative humidity. The project was repeated as before. In addition to the quality analysis every three months, a trained sensory panel of 11 people completed a sensory evaluation to describe organoleptic changes due to storage condition and time.

Dissemination of results occurred throughout the project period at the California Walnut Board Grades and Standards Committee Meetings, the American Society for Horticultural Sciences Annual Conference in 2017,

and individual meetings with walnut processors. Dissemination of results will continue past the end of the grant period in an effort to further educate the industry on project findings.

Significant results generated by the project include the importance of temperature in maintaining quality during storage. Figure 1 depicts the peroxide values for walnuts stored at 40 percent and 60 percent relative humidity for both years of the project (the 20 percent treatment for Year 1 and the 80 percent treatment for Year 2 were removed to examine similarities between the years). The effect of temperature was clear, but relative humidity did not have a significant impact on peroxide formation. Even after six months of storage, peroxide values were significantly higher in walnuts stored at 77°F. Storage at 41°F was able to delay significant peroxide formation over time compared to the other storage temperatures (Figure 2). Higher temperature also resulted in an increased rate of kernel darkening and darker final walnut color (Figure 3).

Higher storage temperatures also corresponded to increased free fatty acid development, but relative humidity of storage was significant as well. Figure 4 shows the development of free fatty acids for Year 1 (including the 20 percent treatment) and Year 2 (including the 80 percent treatment). Walnuts stored at 60 percent relative humidity had higher free fatty acids over time than walnuts stored at 40 percent, but the interaction of temperature also increased free fatty acids as walnuts stored at 60 percent and 77°F developed more free fatty acids than walnuts stored at 60 percent and 41° or 59°F (Figure 5).

The effect of storage condition on organoleptic properties was also observed. Detectable rancidity was significantly impacted by storage temperature and increased over time (Figure 6). Other organoleptic qualities associated with texture, aroma, and taste are shown in Table 1. Many flavor attributes were significantly impacted by temperature while the relative humidity in storage had an impact on many of the textural attributes.

Water activity was not found to play as big a role as initially proposed (data not shown), but relationships between moisture content, water activity, and quality degradation over time are still being investigated through continued statistical analysis and the creation of moisture sorption isotherms (Figure 7) for each walnut variety.

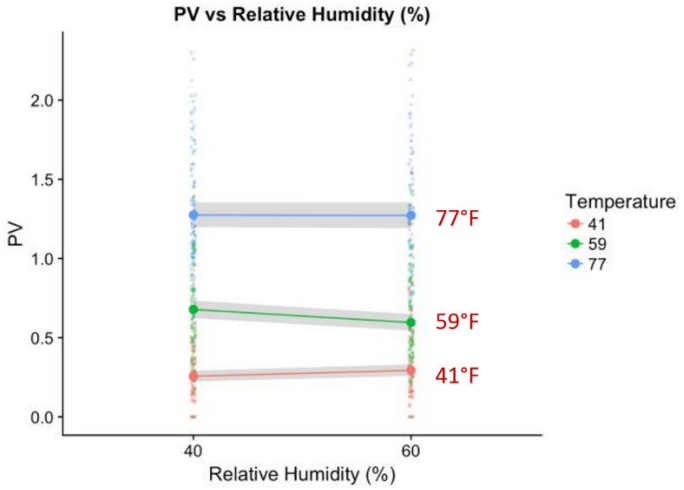


Figure 1. Average peroxide formation for all varieties following storage at 40 percent or 60 percent relative humidity in walnuts stored in year 1 and 2. The effect of relative humidity was not significant, but higher temperatures led to higher peroxide values (PV).

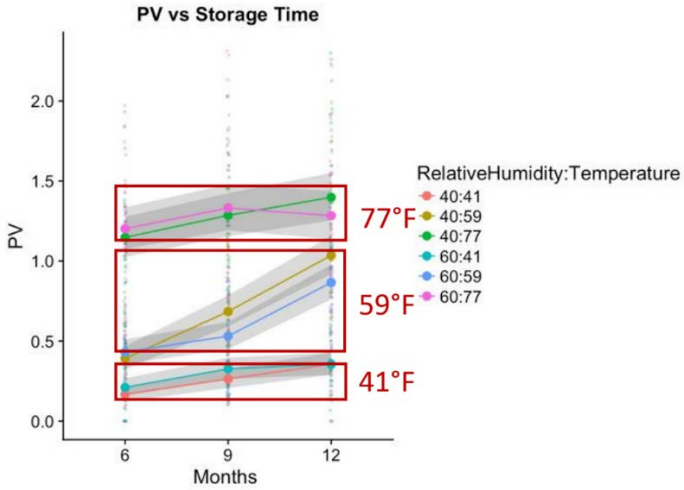


Figure 2. Higher storage temperatures led to increased peroxide formation (higher peroxide values (PV), an indication of oil oxidation and rancidity) even after as few as six months of storage.

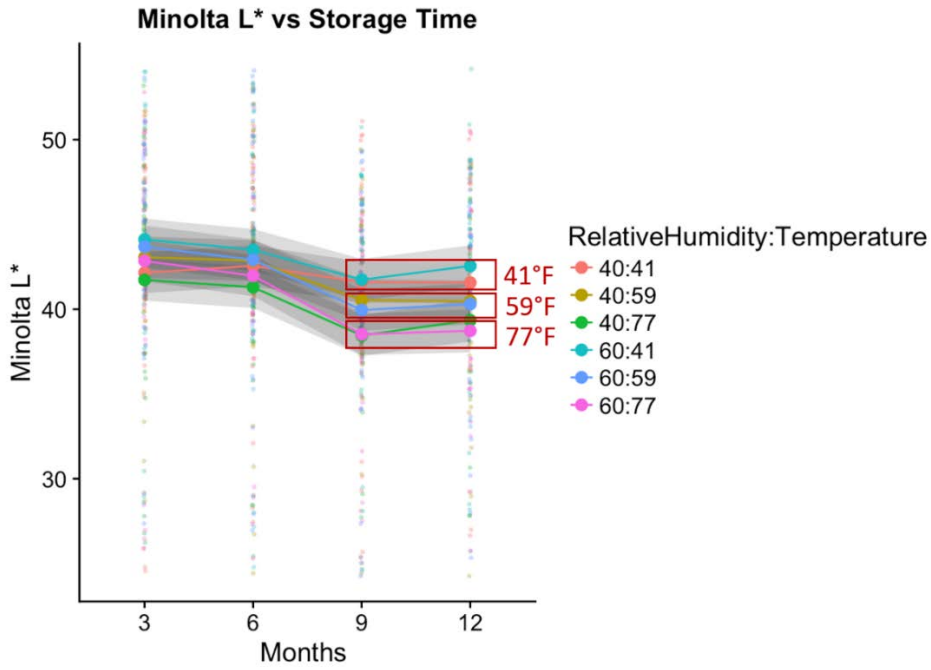


Figure 3. Changes in kernel color over time. Temperature had a significant impact on Minolta L* value. A decreased L* value equates to a darker colored walnut.

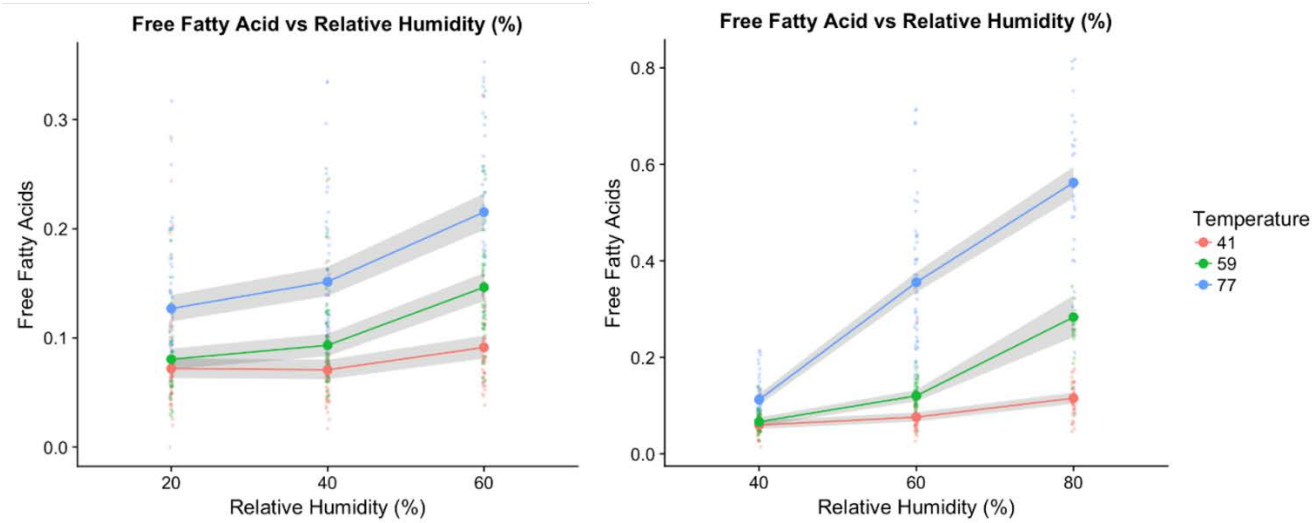


Figure 4. Free fatty acid development during year 1 (left) and year 2 (right) storage of walnuts. Storage at higher relative humidity led to increased free fatty acid development. This effect was compounded by higher temperatures.

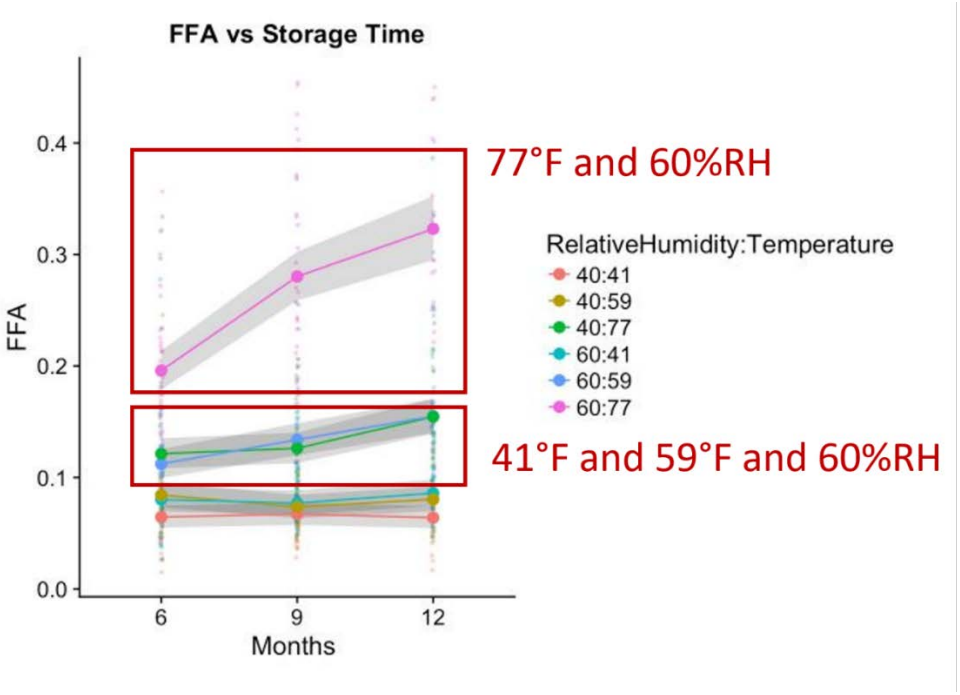


Figure 5. Free fatty acid development over time during storage. Storage at 40 percent relative humidity significantly decreased free fatty acids. At 60 percent relative humidity, temperature of storage conditions became more important with higher free fatty acid development at 77°F.

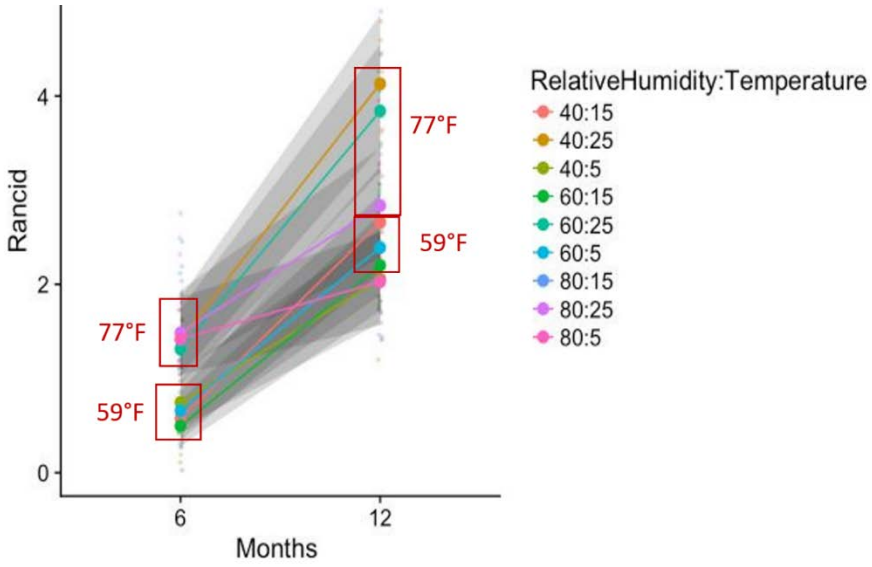


Figure 6. Increase in rancid flavor score from the descriptive sensory panel in walnuts stored six or 12 months under different storage conditions.

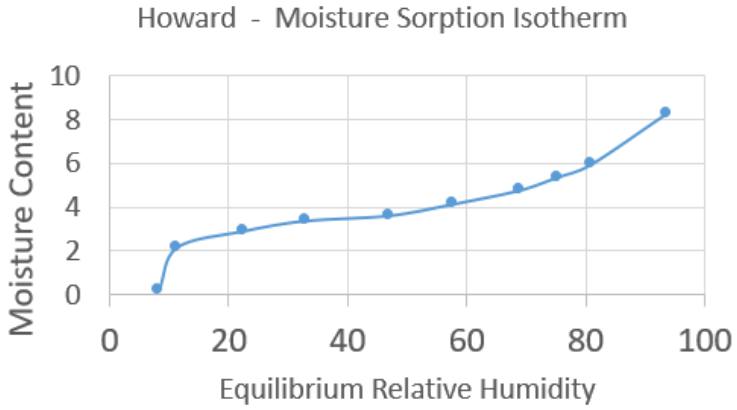


Figure 7. Moisture sorption isotherms were created to better understand the moisture content at various relative humidity levels during walnut storage. The data in this figure is for Howard walnuts.

	Intensity	Rancidity	Nutty	Plant Material	Buttery	Earthy	Astringent	Bitter	Sweet
Variety	***	*					***	***	***
Time	***	***	***		***	***	***	***	*
Temperature	***	***	**	**		**		*	***
Relative humidity (RH)			**						
Time:Temp								*	
Time:RH	**	***							
Temperature:RH		*							
Time:Temp:RH					*				

	Resilience	Crunchy	Dry	Chewy	Oily Mouthfeel	Particulates	Toothpacking	Stiffness
Variety								
Time	***	***	***	***	***		**	***
Temperature	*	*	***	***				*
Relative humidity	*	***		*				***
Time:Temp	***	***	***	***				***
Time:RH		**	***	***				***
Temperature:RH	***	***						***
Time:Temp:RH	***	***		**	*			***

Table 1. The significance of experimental factors (left column) on organoleptic attributes (top row) analyzed by a trained sensory panel. The number of asterisks indicates how significant the effect was statistically, with three being the most significant and an empty box corresponding to no significance.

This project did not benefit commodities other than walnuts; therefore, it solely enhanced the competitiveness of specialty crops.

Fellow colleagues from the University of California, Davis provided advice and guidance for the design of the study. Diamond of California sourced walnuts for both years of the experiment and provided labor for shelling the walnuts to be stored as kernels. The California Walnut Board assisted in distributing surveys to walnut processors and allowed for attendance of project staff at their Grades and Standards Committee Meetings to discuss project updates with the industry. The Guerra Nut Shelling Company provided additional walnuts in Year 2 of the project.

Goals and Outcomes Achieved

At the onset of the project, walnut storage operators were surveyed to assess currently utilized storage practices, quality issues during and after storage, and knowledge of water activity. Walnuts varieties Chandler, Howard, Tulare, and Vina, from two harvest dates, were obtained from Diamond of California as both in-shell walnuts and shelled walnut kernels. Storage conditions were established at 41ºF, 59Fº, and 77ºF in a factorial with 20 percent, 40 percent, and 60 percent relative humidity at each temperature. Both in-shell nuts and kernels were stored at each of the nine storage conditions. Evaluation of walnut quality was assessed immediately at harvest and again every three months during storage up to the 12-month mark.

Walnut quality evaluation included kernel color, whole walnut and kernel moisture content and water activity, presence of mold, and walnut oil oxidation. Kernel color was evaluated using both a Minolta Chromameter and a walnut color chart developed by the California Department of Food and Agriculture. To determine moisture content, walnut samples were chopped to uniform size and weighed, then dried in an oven for 48 hours, and then weighed again. Water activity was determined using an AquaLab 4TE DUO Dew Point Moisture Analyzer. Presence of mold was evaluated visually. Walnut oils were extracted using a hydraulic press and analyzed by chemical titrations for the development of free fatty acids and peroxides.

After receiving the survey results indicating that most storage operators do not monitor or manage relative humidity in their walnut operations, the second year of the study was modified to better mimic ambient conditions by including storage at 40 percent, 60 percent, and 80 percent instead of 20 percent, 40 percent, and 60 percent. Quality evaluations were completed every three months as previously described for Year 1 quality analyses. In addition to the change in storage conditions, the Year 2 analysis differed by including a trained sensory panel to evaluate organoleptic differences in walnuts stored under different conditions at the 6-month and 12-month quality evaluations.

Both throughout the duration of the project and following the completion of the study, results were discussed with those in the industry to contribute to the expected measurable outcomes of educating walnut processors and storage operators on optimum walnut storage conditions.

Outcome measures were focused on the walnut processors' understanding and utilization of results gathered from the study to improve storage conditions. Throughout the grant, project staff have been in contact with the walnut industry through emails, conference calls, consultations, and presentations at committee meetings. While the initial project proposal included a follow up survey similar to the original web-based questionnaire, project staff completed in-person interviews with walnut processors following presentation of the project results. These interviews granted greater discussion of currently utilized storage practices, issues related to

storage, and desires to alter practices after receiving knowledge from the presentation than a follow up web-based survey would have provided.

Goals established for the project initially included the distribution of a web-based survey to walnut processors following the completion of the project. This survey was designed to test changes in knowledge and understanding of water activity and how it influences quality degradation, a change in the use of water activity during walnut storage, and a desire by walnut processors to modify storage conditions to reduce the rate of deterioration during storage. These goals were altered by the decision to complete in-person interviews. This allowed project staff to confirm information about currently utilized storage practices, quality issues encountered, and desire to change storage practices after learning about the project results. These goals were further altered due to the results from the project. Because water activity was found to not be as closely related to quality degradation than initially hypothesized, the follow up interviews focused on the importance of storage temperature and relative humidity on quality degradation rather than specifically on the importance of water activity. Instead of asking about the desire of processors to monitor and manage water activity, project staff focused on the discovered importance of temperature and relative humidity on quality degradation and processor's desire to alter these conditions based on the project's results.

Following the initial survey to the walnut industry, project staff learned that most walnut processors do not control for relative humidity and a majority do not control temperature in their storage operations. After presentations of results generated from the project highlighting the importance of optimizing storage conditions, especially temperature, walnut processors and handlers expressed interest in altering their storage practices to reduce the rate of quality deterioration based on the project's findings. The processors and handlers discussed moving their product into temperature controlled storage rooms earlier in the storage season, installing more temperature controlled storage rooms, and using night ventilation to reduce the temperature in storage silos. There was a clear recognition of the need to adjust practices if better quality after storage were to be achieved.

While this is a start to the extension efforts to educate the industry on project findings of walnut quality over time under different storage conditions, project staff will continue to attend meetings of walnut processors and handlers to present project findings in an effort to optimize storage conditions along each sector of the postharvest supply chain. Project staff will also prepare a fact sheet that demonstrates optimum storage conditions for walnuts. Project staff will provide the fact sheet to California walnut handlers through the California Grades and Standards Committee.

Summary of Project Goals, Targets and Outcomes:

Goal 1: California walnut processors and storage operators understand the relationship between water activity and the rate of quality deterioration for the main walnut varieties.
Target: At least one individual from the storage facilities that handle 80 percent of the production will develop an understanding of these relationships.
Outcome: After testing four walnut varieties it was determined that water activity was not directly correlated with walnut quality degradation as initially proposed.

Goal 2: Walnut storage operators begin to measure water activity of their nuts in storage.
Target: The storage operators who handle 50 percent of the production will begin measuring water activity.

Outcome: Project staff have not seen any results that indicate industry adoption of water activity as a standard analysis in their facilities.

Goal 3: Walnut processors modify their storage or shipping conditions (temperature and relative humidity) to achieve more optimal water activity and reduce the rate of walnut quality deterioration.
Target: Storage facilities handling 30 percent of the production plan to improve storage practices in the near future by the end of the project, and 50 percent of the production will be stored under more optimal conditions, based on water activity, within five years of the end of the project.
Outcome: Walnut storage processors responsible for 20 percent of the crop (based on 2016 production numbers) indicated a desire to make changes to operations or storage facilities based on project findings. This was all of the processors project staff met during the grant period. Meetings with walnut processors and other industry members will continue after the project so project staff can reach a larger percentage of the industry.

Additional successful outcomes of the project include the following:

- Clear demonstration of the importance of low temperature storage on the rate of deterioration of walnut quality during storage, and the secondary importance of relative humidity.
- Increased understanding by California walnut processors and handlers of the changes in storage practices required to reduce the rate of walnut quality deterioration.

Beneficiaries

Operations that benefit from the completion of the project's accomplishments include walnut processors, handlers, storage operators, wholesale distributors, and retail venues. As there are many sectors of the postharvest chain that are responsible for storing walnuts before they are purchased by the consumer, all of these could be benefitted by enhanced knowledge of the impacts of storage conditions on deterioration of walnuts. While the project staff's primary focus was walnut processors, handlers, and storage operators who are responsible for great quantities of walnuts at a time, this knowledge could be expanded to influence more parts of the postharvest supply chain, thus greatly enhancing the walnut product that is received by the consumer.

Improved knowledge of the effects of storage conditions on walnuts will impact about 100 walnut processors and indirectly impact approximately 4,000 walnut growers. The walnut industry had a total value of $976 million in 2015 with export value of $1.48 billion. Reducing the rate of walnut degradation will improve quality and increase buyer and consumer satisfaction, which may increase demand for walnuts. Ultimately, the industry hopes that more snack food producers will consider using walnuts if their shelf life can be extended.

Lessons Learned

Project staff experienced issues with insects in the product during both years. Although walnuts were fumigated prior to being donated, they were temporarily stored at a scale house where project staff believe they were infested. In the first year, project staff used carbon dioxide gas to treat all of the tanks of product to kill insects. In the second year, project staff implemented insect control treatments of all tanks at the start of storage to avoid problems, but still found insects in one of the storage conditions. A second treatment was applied at this time.

A sensory analysis was initially proposed for each harvest date (early and late harvest) and storage type (in-shell or kernel) for each variety stored at each combination of relative humidity and temperature. Due to the factorial nature of the project and the duration of time needed to complete a sensory analysis, the samples included in the sensory analysis were decreased by 25 percent to exclusively include the early harvest and in-shell storage type. Even this diminished number of samples required approximately nine hours of sampling per individual panelist. While a descriptive sensory analysis has its merits, a less in-depth consumer sensory survey will be considered in the future to decrease the time consumed and increase the number of samples that can be analyzed in a given time.

The postdoctoral researcher initially in charge of the project left the university after the first three months of storage for Year 1. While replacement with a Junior Specialist to manage the project was rapid, better organization and documentation prior to replacement would have facilitated an easier transition for project staff. The importance of detailed methods and well-documented organization was highlighted and improved over the duration of the project.

After discussions with the walnut industry, it became apparent that walnuts stored in the project staff's lab did not undergo hydrolytic and oxidative rancidity to the extent that walnut handlers and processors observe in their stored walnuts. The values for free fatty acids, peroxide values, and rancidity, even after 12 months of storage, were not as dramatic as those seen by the walnut industry. Since project staff were trying to decrease variation due to factors that they were not interested in studying, project staff did not use cracked, scuffed, or broken walnut kernels. Kernels and in shell walnuts that were placed in storage were checked to make sure they did not have injuries that would increase oxidation in an effort to maintain consistency within the treatments. While this is good for experimental design, it likely did not show the full extent of rancidity development that occurs in walnuts under real-world conditions. Future studies could sample walnuts from actual walnut storage facilities to better understand the quality degradation that occurs in a more realistic commercial setting.

While the importance of storage temperature on oil oxidation (both peroxides and free fatty acids), walnut taste, and kernel darkening and the effect of storage relative humidity on free fatty acid development and textural changes was clear, water activity was not directly correlated with walnut quality degradation as initially proposed. Project staff are continuing to explore differences in the relationship between water activity and the rate of deterioration between walnut varieties to determine if within variety relationships can be determined even though no relationship was observed across the four varieties tested.

Outcome measures that were not achieved refer specifically to the education and implementation based on water activity, assuming that water activity would be an important measurement for walnut quality degradation. While project staff have not seen any results that necessitate industry adoption of water activity as a standard analysis in their facilities, project staff are teaching walnut processors the important effects of storage temperature and relative humidity on the rate of walnut quality deterioration.

Additional Information

No additional information.

USDA Project No.:	Project Title:	
10	Promoting California Pistachios and Dried Plums (Prunes) as Ingredients in China	
Grant Recipient: American Pistachio Growers	**Grant Agreement No.:** SCB15010	**Date Submitted:** December 2017
Recipient Contact: Haiying Zhang	**Telephone:** (559) 475-0435	**Email:** HZhang@AmericanPistachios.org

Project Summary

American Pistachio Growers (APG) and the California Dried Plum Board (CDPB) proposed hosting a series of culinary and baking seminars to promote pistachios and dried plums as ingredients to the hotel industry in China and Hong Kong. This series was a continuation of the "Bakery Seminars" conducted by APG and CDPB in Korea and Japan in 2014 and was based on the success of these seminars. While pistachios and dried plums have not been widely used as bakery ingredients by the China and Hong Kong hotel and restaurant sector in the past, through hosting these seminars, APG and CDPB endeavored to create a new demand among the trade, and to maximize the potential of the rapidly growing hotel and restaurant sector of this market.

Over the last several years, China and Hong Kong have been important export markets for both California pistachios and dried plums. However, most pistachios and dried plums are purchased at the retail level by consumers seeking healthy snack options. Furthermore, while purchase of U.S. pistachios among foodservice professionals has increased in recent years, it remains a largely undeveloped channel for pistachios and dried plums. Distributors and foodservice professionals that source pistachios frequently mix products from multiple origins to reduce costs. To build awareness and demand for California products, APG and CDPB sponsored baking seminars encourage the utilization of pistachios and dried plums as ingredients.

This project built upon the 2013 Specialty Crop Block Grant Program Project 7: *Baking Seminars for Food Professionals in Japan and South Korea*. The project implemented five successful bakery seminars and two recipe contests in Japan and South Korea in the spring of 2014. This project was part of an overall objective by APG and the CDPB to create demand among foodservice professionals in Asia. Following the completion of the baking seminars, 384 participants received a survey requesting evaluation of the event. Of all respondents, 98% indicated their experience was 'good' or 'excellent.' A total of 93% indicated they would use or recommend the use of California pistachios and dried plums in their business.

Through the current project, progress built upon and applied successful tactics that were used in South Korea and Japan to reach luxury hotel chefs in China and Hong Kong. To accomplish this objective, APG and the CDPB hosted multiple cooking seminars in Shanghai, China's largest and most prosperous city, and Hong Kong, a large import hub and top tourism destination for Asia region. Both cities maintain a high concentration of luxury hotels, restaurants, and professional bakers, and show positive signs for future growth.

Project Approach

The following table outlines APG/CDPB's work plan activities and indicates the timeframe in which they were completed:

Activities	Completed
Coordination of in-country representative and chef; Preliminary event organization	October 2015 - January 2016
Kick off meeting and contract negotiation with celebrity chef Nancy Silverton and in-country representative	January 2016
Developed curriculum for seminars, including recipe development, recipe photography, and recipe book layout and design; worked with three, U.S. based contracted chefs to develop additional recipes for inclusion in recipe book that contained at least 51% specialty crop ingredients	January 2016 – April 2016
Organized all seminar logistics including identifying qualified attendees, securing space in Hong Kong and Shanghai and developed supporting materials (including translation to traditional and simplified Chinese).	January 2016 – May 2016
Invitations to attend baking seminars were distributed and responses monitored	February 2016 – April 2016
Planned trip by in-country contractor to the seminar locations to finalize the event details. Travel included a trip from Shanghai to Hong Kong.	May 2016
Post-seminar survey was prepared	April 2016
Pre-seminar coordination (ensuring all raw materials were purchased and sent to venue locations; coordinating Chef Silverton's presentation and demonstration with in-market agency; provided equipment list necessary for Chef Silverton's work; other required plans and preparations between Chef Silverton and in-market agency)	May 2016
On-site day-before and day of preparation and recipe demonstration (assisted in set-up on location at each seminar venue; assisted in demonstration during event to support Chef Silverton's presentation; fielding relevant questions and requests from attendees)	June 2016
U.S. delegation (APG, CDPB, two growers, and celebrity Chef Nancy Silverton and Dahlia Narvaez) traveled from California to Shanghai to perform the first series of baking seminars.	June 2016
Two baking seminars hosted in Hong Kong and three baking seminars hosted in Shanghai (nine day trip). Prior to each baking seminar, one day of preparation is required. APG contracted with the bakers, chefs and a coordinator associated with the hotel (Shanghai) or training vocational (Hong Kong) venues where the events took place. Following preparation and orientation, these individuals were available to assist on the following day at the seminar. Surveys were conducted immediately following the baking seminars.	June 2016
The U.S. delegation (two APG, two growers, Chef Silverton and Chef Narvaez, and the two in-country representatives traveled from Shanghai to Hong Kong to perform the second series of seminars.	June 2016
Export data was collected on a monthly basis following the conclusion of the baking seminar series. Beginning in August 2016, APG accessed the United States Department of Agriculture's (USDA) Global Agricultural Trade System (GATS) to determine monthly changes in U.S. pistachio export volume and value.	August 2016 – February 2017
Assessed results of baking seminars including following-up with participants to identify the likelihood of developing recipes using pistachios and dried plums. Quarterly newsletters were also distributed to participants.	July 2016 – December 2016

Activities	Completed
Follow-up evaluations were conducted six months following the conclusion of all five baking seminars in Hong Kong and Shanghai.	August – December 2016
APG/CDPB worked with in-country contractor to organize and coordinate a Recipe Contest. List of participants were contacted for interest and recipe submission, advertising was conducted on APG website, social media and other associated media platforms, and contest rules were communicated to participating seminar attendees. Once participants were identified, APG/CDPB worked with in-country contractor to send ingredients to each participant for use in recipe formulation.	October 2016 – November 2016
APG/CDPB worked with contractor to collect recipe submissions per collection guidelines. Recipes were translated to English.	November 2016
In-country contractor sent APG a minimum of 80 recipes translated in English, formatted in correct recipe format, and with accompanying photos. Once prepared, contractor/APG sent all recipes to each of four US based chef judges. Each chef judge received 20 – 30 recipes for review.	December 2017
US judge panel reviewed and rated recipe submissions according to guidelines. Final selections by each US-based judges—one featuring pistachios, one featuring dried plums—were submitted to APG.	January 2017
In-country contractor announced winning recipe selections, alerted winning participants, and began announcement work across all APG/CDPB associated media platforms and the China Bakery Association's website. The contractor finalized the design for printing each recipe in a double-sided, full color, binder addition page. The contractor mailed each seminar participant copies of the eight winning recipe pages to be included with binder.	January 2017

Pistachios and dried plums are the only commodities that benefited from this project.

APG and the CDPB both made significant contributions towards this project, with the assistance of APG's export program consultant and in-country representative. The groups worked closely on many of the activities related to the grant. Staff from each group provided oversight of all grant activities and ensured that all program expenses met the approved budget.

Furthermore, APG Vice President, and, APG Asia Marketing Director, traveled to the Shanghai and Hong Kong seminars to coordinate the seminars, present on the specialty crops, and provide informational materials information about American pistachios. Additionally, APG growers traveled to speak at the seminars about their work and experience in the pistachio industry. At the seminars, two chefs conducted demonstrations of several recipes using pistachios and dried plums, and spoke about their versatility, nutritional value, and functional benefits in a variety of sweet and savory recipes. All six travelers worked with the in-country representative to coordinate the seminars and communicate with seminar attendees and other contacts during the event. The in-country representative also coordinated with APG to successfully execute a bakery recipe contest as a follow-up event to the seminars which utilized a U.S. judging panel. Recipe submissions were translated and submitted to APG and the U.S. judging panel for review. Finally, the in-country representative announced the winners of the contest and designed and printed recipes for distribution to seminar participants. The recipe contest activity sought to maintain the engagement and interest in pistachios and dried plums among attendees that was initially established during the baking seminars in June 2016, and encourage them

to work first-hand with the specialty crops, while also generate publicity for participation and creativity around opportunities for chefs and other professionals to utilize the specialty crop in their work on a regular basis.

Goals and Outcomes Achieved

The project objective was to increase consumption of California grown pistachios and dried plums as an ingredient among the hotel and baking industry in China and Hong Kong. In order to achieve this, APG and CDPB: 1) utilized surveys to track seminar attendee's increase in awareness, knowledge, and likelihood for utilizing the specialty crops in the future; 2) continue to work with the in-country representative to track the number of menu items in Shanghai and Hong Kong using pistachios and dried plums; 3) collected recipe entries for the baking contest, which provided a measurement of continued engagement among seminar attendees; and 4) continue to use export databases to monitor and record the level of pistachio and dried plum exports to the region.

The longer term, or ongoing measure includes monitoring the export sales value and volume of pistachios and dried plums to the China and Hong Kong region by using the USDA GATS which provides value and volume data for U.S. exports of pistachios and dried plums by their respective HS codes.

Attendance
Goal: Achieve a minimum of 70 attendees per seminar in Hong Kong and 90 attendees per seminar in Shanghai.
Result: For the two seminars in Hong Kong, average attendance for each reached 80, surpassing the goal. For each of the three seminars in Shanghai, attendance reached 90, 95, and 100, respectively, meeting or surpassing outlined goals. APG/CDPB's bakery seminar series in both cities reached a total of 445 members of the market's sector, primarily decision makers from restaurants, ingredient companies, commercial bakeries, baking schools, and hotels.

Post-Seminar Survey
Goal: Achieve post-seminar survey results of 90% or higher for positive responses on the final survey question gauging attendee's use of the specialty crops in the future.
Results:
- For Shanghai seminars, out of 191 total surveys received, 97% of surveyed attendees indicated that they would specify California pistachios and prunes in their businesses in the future.
- For Hong Kong seminars, out of 115 total survey respondents, 100% indicated that they would specify pistachios and prunes in their businesses in the future.

All survey results include the following:

Survey Question	Shanghai Results	Hong Kong Results
Please rate your overall experience at this seminar (*5 being highest rating*)	4.69	3.99
Event facility	4.89	4.06
Recipes produced for this seminar	4.73	4.16
Recipe book and educational videos	4.73	4.05
Did you find these recipes new, innovative, and inspiring to your business?	4.59	3.87
The above are average results, on a scale from 1-5, with 5 being the highest.		
Do you currently use pistachios in your baking and desserts?		
Yes	63%	69%
No	37%	31%
Do you currently use prunes in your baking and desserts?		
Yes	43%	43%
No	57%	57%
As a result of this seminar, will you specify pistachios from California in your business in the future?		
Yes	97%	100%
No	3%	0%
As a result of this seminar, will you specify prunes from California in your business in the future?		
Yes	95%	100%
No	5%	0%
Have you learned anything new about California pistachios and prunes at this seminar?		
Yes	99%	95%
No	1%	5%
Would you recommend this seminar to other bakers or chefs?		
Yes	99%	97%
No	1%	3%

Hotel and Restaurant Sector Menu Item Surveying
Goal: APG/CDPB will work with the in-country representative to monitor and track the number of establishments offering pistachios or prunes as ingredients in menu items. The goal is to see an increase in the regular offering of these products.
Result: In a pre-seminar screening of many of the attending hotels, restaurants, and bakeries, a majority of them had not utilized pistachios or dried plums as ingredients before attending. As a result of the education received through APG/CDPB's bakery seminars however, the demand and regular usage of pistachios and prunes as ingredients were found to be more widely used in establishment's menu items. The resulting percentage is 32.7% of responding establishments—that is, out of 327 outlets surveyed, 20 in Hong Kong and 87 in Shanghai (for a total of 107) reported that they now utilize or have featured pistachios or prunes as ingredients on their menus.

Specialty Crop Exports
Goal: APG/CDPB will collect and analyze export data for increases in export sales of the specialty crops.
Results: According to the USDA GATS during the period following the baking seminars (between August 2016 and January 2017) exports of U.S. pistachios (in-shell and kernels) to China and Hong Kong reached 67,531 MT valued at over $473.9 million. Between August 2015 and January 2016, U.S. pistachio exports (in-shell and kernels) to China and Hong Kong reached 13,258 MT valued at $129.1 million. Year-on-year, this represents a 409% increase in volume and 267% increase in value for the period following APG/CDPB's baking seminars.

The rationale behind measuring total pistachio exports (in-shell and kernels) is that China primarily imports raw (in-shell) pistachios to then have processed domestically into kernels used in the hotel and restaurant sector as ingredients. There is an advantage to this in that tariff rates are less burdensome for raw, in-shell product, and labor for shelling is also less expensive in China.

For U.S. dried plum exports (HS code: 0813200000) to China and Hong Kong combined during 2016 experienced a 19% decline in volume, but an 11% increase in value over 2015, reaching 2,460 MT and $9.38 million. The 2016 export levels for U.S. dried plums reached the highest value returns since 2014.

For the period just following the baking seminar events (August to December 2016) dried plum exports reached 837.8 MT worth more than $3.1 million, representing a slight decrease in volume—but an increase in overall value—when compared to the same period during 2015 (886.8 MT and over $2.6 million). The lower volume during the recent year was due primarily to a pending short crop in California. The results of the seminars, however, will produce long-term benefits for California prunes in the China and Hong Kong hotel and restaurant market.

While it is difficult to measure the exact impact that the bakery seminars APG and CDPB conducted in China and Hong Kong during 2016 had on overall specialty crop export levels, the data being tracked via the USDA database provides insight into the market's overall demand trends and sales potential for these ingredients. APG/CDPB utilize this data to determine market trends and identify targeted audiences to provide education and resources that encourage future sales. These efforts ultimately build a reliant source of export revenue for some of California's most valuable export crops, ensuring profitable returns for growers.

Bakery Recipe Contest
Goal: Fifty to 85 recipe contest entries.
Results: In total, 180 participants submitted entries, half for recipes with pistachios and half with dried prunes. Media results for the announcement of the eight winning recipes reached around 100,000 viewers, mostly hotel and restaurant professionals and consumers, through placement on social network platforms for the China Bakery Association and the China Food Industry Association.

Furthermore, all of the recipes submitted through the contest were new creations, and already 60% of participants from the contest that developed new recipes have expressed their willingness to include their recipes as a regular menu item in their business should they find the appropriate purchasing source.

Baseline data and progress to date includes the export levels for U.S. pistachio kernels and dried plum exports to China and Hong Kong combined, whereby during the 2016 year total U.S. pistachio kernel exports reached

73,504 MT worth over $527 million. Annual U.S. dried plum exports to China and Hong Kong for the 2016 year reached 2,460 MT and $9.38 million. These represent an increase in export value across both crops, and an increase in volume for kernel pistachios. These data points will serve as baselines against which future export sales for the specialty crops will be collected and analyzed, helping APG/CDPB to monitor market trends and potential, and identify opportunities for building on educational efforts.

Major successful quantifiable outcomes of project activities include a total seminar series reach of 445 attendees from key hotel and restaurant sector professions; 12 organic media hits of media coverage for the seminars on key online and print platforms; 180 recipe contest entries from seminar participants four months following the seminars; and 16 media placements for the recipe contest on key online and print platforms worth an ad value equivalent of $48,000 USD.

Beneficiaries

The beneficiaries to this program are 1,850 California pistachio and dried plum growers. Since 2004, the number of pistachio bearing acres in California increased by over 200 percent. In order to support this growth, while maintaining strong prices and returns to growers, APG must continue to generate new demand through building export markets. California also produces an average of 393,740 tons of dried plums annually, making this the 17th largest export crop in California. Furthermore, California is home to upwards of 49,000 acres of dried plum trees and accounts for 48 percent of the world's supply. Additionally, food and ingredient safety and quality is a major concern among the hotel and restaurant sector in China and Hong Kong and their consumers. The completion of this project has provided this sector with important resources and contacts within the California pistachio and dried plum industry, which is well known to provide the highest quality specialty crop products.

Combined, 1,850 California grower families statewide will benefit from this project. These growers generate more than 10,000 locally employed jobs.

Lessons Learned

Overall, APG/CDBP is satisfied with the outcomes of the bakery seminars and bakery recipe contest that were conducted. APG/CDPB achieved significant outreach to the hotel and restaurant sector in the targeted market, conducted highly professional, educational, and engaging seminar events, and received a high level of bakery contest participation from seminar attendees. These outcomes demonstrate the interest and demand for education and information on California pistachio and dried plum specialty crops, and the market potential for future export sales. The baking seminars also allowed APG/CDPB to build on their relationships with some of China’s key bakery and tree nut organizations and other major hotel and restaurant contacts, paving the way for future collaborative partnerships, events, or promotional activities.

Should APG/CDPB conduct future activities similar to the bakery seminars, one idea to improve could be working closer with these in-market organizations to provide additional outreach to targeted audiences. Another lesson learned during the planning and implementation of the project was the difficulty in coordinating two seminars in Shanghai to occur on the same day, and the limited time spent in-country ahead of the seminar dates to prepare. While the execution of each of the seminars was professional and successful, APG/CDPG would improve the timing and planning in working with the venues and partners just ahead of the events to ensure smoother day-of preparations.

Additional Information

Attached to the report submission are three PDF files containing activity summaries, results, and professional photos of the baking seminars in Shanghai and in Hong Kong, as well as the follow-up recipe bakery contest.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 11	**Project Title:** Online Marketplace four Nursery Growers: Connecting Growers of Nursery Crops with Buyers in a Bilingual, Virtual Marketplace	
Grant Recipient: California Association of Nurseries and Garden Centers	**Grant Agreement No.:** SCB15011	**Date Submitted:** December 2018
Recipient Contact: Karli Quinn	**Telephone:** (916) 448-3900	**Email:** karli@agamsi.com

Project Summary

The California nursery industry is represented in 55 out of 58 counties. Combined, the nursery and floral industry's production was ranked fourth in California agricultural commodities. A 2013 report from the University of California, Davis (UC Davis) estimates the total output and employment impacts of California flower and nursery production and lawn and garden retailing in 2011 at $11.29 billion and 184,202 jobs. This reflects not the peak of value and employment but a gradual recovery from the 2007 economic recession. Consumers demand a wide variety of plants to enhance their landscape. Both geographic isolation and language barriers can make it difficult for growers to provide wholesale buyers and ultimately consumers with information about which plants are currently available and which plants are well-suited to various climates. This project created an online marketplace for the nursery industry where growers, producers and buyers can easily and effectively communicate both plant availability and buyer preferences. This project enhanced the ability of these specialty crop producers to market their product in an increasingly important digital medium. The project also helped identify potentially invasive plants and provided substitution recommendations as recommended by the PlantRight program with which the California Association of Nurseries and Garden Centers (CANGC) had a working partnership. The display, plant education, and buyer/seller interaction necessary for nursery growers to successfully market a diverse range of plants once took place at large, regional trade shows. Many industries, including the nursery industry, no longer have the capacity to organize these large trade shows. As such, growers and producers have struggled to reach growers in an organized, systematic fashion resulting in diminished sales.

According to a 2013 report from UC Davis, nursery and flower producers are rather unique among California farmers in that a large number continue to be located in the most urbanized areas of the state. Five of the nine California counties with population exceeding one million persons in 2013 (Los Angeles, Orange, San Diego, Santa Clara, and Riverside) were among the largest nursery and flower producers and have a combined population of 20.29 million. The online marketplace will be especially impactful to small growers without infrastructure to seek out retailers, further connecting rural production and urban consumption.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The project staff developed a multiple page consumer and grower facing website that was then translated into Spanish to serve as a medium between nationwide buyers and California growers who speak both English and Spanish. The project staff worked with a Portland- based web team, who developed a similar site for the Oregon Nursey Industry, to develop a website with an extensive plant database. This database came from a Plant Science expert based out of UC Davis. This website has a backend user platform where the California growers can upload and promote the California specialty crops, they have available for retail sales. The

project staff contracted with a Sacramento-based translation team who translated every page into proper Spanish language. This translation team developed video tutorials to introduce the site to growers and walk them through the process of uploading their plant lists. Project staff attended trade shows and worked with each team to see the project along.

This website connects buyers with California nursery growers and adds to the total sales of California grown nursery products. Buyers can now be connected via the internet and are able to connect with California horticulture and nursery crop growers whom they once could not connect with for reasons such as language barriers or lack of information. Once the website was live, association staff monitored grower profiles and uploads, and had to approve posts before their plant lists were published to the website.

Goals and Outcomes Achieved

The project staff developed and released a request for proposal for web and database professional, receiving three in total and selecting one based out of Oregon due to the fact they had experience in developing a similar website for Oregon's nursery industry.

The project staff selected contractor from UC Davis for the plant database professional due to the extensive knowledge and experience in plant science as well as being bilingual in English and Spanish. The contractor was able to serve the association as the outreach coordinator as well.

A request for proposal was made for an outreach program provider who engaged growers and buyers through social media, industry publications and other communication mediums. CANGC selected public relations and communications contractor due to their extensive knowledge in the agricultural industry as well as working with California specialty crop grants.

Development of online marketplace and database: There were many roadblocks in the process of bringing this project to fruition. The data set needed to create the backend database for the website took longer than anticipated. The project staff were not able to use the photography originally planned due to copyright issues. These issues contributed to the database completion date coming almost a year later than anticipated. In addition, the contracted web team had delays on their end which were unanticipated.

Website and database translated into Spanish: Due to the above delays, the translation team had a very tight timeline. They took this challenge on, translated the site within weeks; they created videos to train growers on how to use the site with ease.

Project staff worked directly with nursery growers to sign up and populate the virtual marketplace at webinars, industry events and growers meetings. Throughout the grant period, staff and outreach coordinator attended events, however, as the website launch date kept being pushed out, project staff made an executive decision to allocate all resources to getting the site functional and live.

The long-term outcome measures will be seen as this website becomes more popular and buyers are successful in finding the plants they need. The project staff have set this site up to be sustainable and are able to add to the number of growers using the site. The project staff have seen the site viewed 23,967 times and 3,238 users uploaded data.

The accomplishments have been delayed due to the site not getting up and running as quickly as originally anticipated; however, project staff have fully launched a site that has growers and buyers accounts set up. The project staff are continuing to promote this site through the association's efforts in the weekly newsletter, CANGC website, on the social media platforms and promotion through the board's individual companies. The project staff anticipate the goals to be met within the year, since the site was launched later than originally anticipated. The project staff are using google analytics to measure the number of users and site visits. Due to unforeseen events causing delays, the association was never able to record start sales data. The project staff opted to track website use and traffic instead.

Baseline data goals shifted from sales data collection to data on website traffic and usage. The initial goal was to increase sales of nursery stock by 10 percent representing an increase of $329 million. The web team informed project staff it would not work to ask growers to fill out a sales sheet prior to creating an account. With the delay in the website launch and the fact that sales sheet information could not be provided prior to creating an account, project staff did not receive baseline data. Although project staff could not determine baseline sales data or display the increase of sales, staff were able to track website traffic usage. Since the site was launched May 1 to July 30, 2018 project staff observed 13,642 pageviews, 1,704 new users and 45 new company profiles added. Data will continue to be analyzed quarterly. July 1 to November 28, 2018 there were 10,325 page views and 1,535 new users.

Beneficiaries

This project created a potential benefit to all 500 growers and 1,900 retail operations with nursery licenses in the state of California as well as in state and out-of-state nursery buyers who would not have been able to access these plants without the Marketplace.

The number of potential beneficiaries is large, project staff have seen 3,238 use the site, so 3,238 have benefitted from the site by posting and leading to potential leads.

Lessons Learned

Website development should have projected a longer timeline than what was originally anticipated. This would have allowed for potential coding errors, and miscellaneous fixes that needed to happen prior to site launch. Anticipated launch date was December 2016 and the official launch date was March 2018. This was an unexpected outcome due to data blocks, coding errors and various unpredicted issues.

The project staff would recommend using contractors within the state where in person meetings can happen more regularly. Also, project staff recommend during the initial phase of the project, to make sure that fundamental website data is achievable within the timeline.

Additional Information

Project website: https://cagrownnurserymarketplace.com

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 12	**Project Title:** Promoting California Specialty Crops Through Education and Enrichment	
Grant Recipient: California Department of Food and Agriculture, Office of Farm to Fork	**Grant Agreement No.:** SCB15012	**Date Submitted:** December 2017
Recipient Contact: Nicole Sturzenberger	**Telephone:** (916) 900-5123	**Email:** nicole.sturzenberger@cdfa.ca.gov

Project Summary

Many Californians suffer from diet-related diseases, often as a result of not consuming enough specialty crops. Efforts to increase the consumption of California specialty crops are a win-win: they support California specialty crop farmers while promoting a healthier diet for California consumers. This project aimed to promote the consumption of California specialty crops through increased specialty crop nutrition education, inclusion in school meals, and outreach.

This project sought to increase California specialty crop consumption and marketability among school age children and the general public. Although the need for increased consumption of specialty crops is recognized, habits are slow to change, making this project timely in its implementation. Research suggested that changes in consumption are most effective early in life, mainly by engaging young children and encouraging them to develop lifelong healthy eating habits. Therefore, many of the activities in this grant focused on engaging students with specialty crops awareness and nutrition education, and improving access to specialty crops for children through the meals they receive at school. Public schools and their meal programs also represented an effective avenue to connect with needy populations across the state.

This project built upon a previously funded 2014 Specialty Crop Block Grant Program Project 18: *Engaging Agriculture within the Local Community: A Project Addressing Food Access, Agricultural Education and Outreach*. The specialty crop Ambassador Program was continued and expanded to include Southern California. This grant also built upon the Mobile Farm business plan, curriculum, and outreach materials created in Project 18. This grant enabled the transformation of those ideas into a detailed design of the Mobile Farm.

The Child Nutrition Director (CND) Trainings complimented and enhanced the work that was done previously on the California Farmer Marketplace (CFM) in both the 2012 Specialty Crop Block Grant Program Project 70: *Farm to Fork specialty crop database – Phase 1*, and the 2013 Specialty Crop Block Grant Program Project 65: *Farm to Fork Specialty Crop Database – Phase 2*. These trainings not only brought attention and highlighted the CFM as an easy way of finding and procuring local specialty crops, but also how including locally grown specialty crops into their school meals is feasible, practical, and makes their meal programs more successful.

Project Approach

Ambassadors: A sub-award was established with Archi's Institute for Sustainable Agriculture to act as the farm to fork ambassador host organization. The project aimed to support a new generation of future specialty crop farmers and use these new farmers as ambassadors, teaching the next generation of the benefit of farming. The Office of Farm to Fork (F2F) reviewed eight applications for specialty crop best practices guides

and projects submitted by students. F2F staff selected six applicants, of which four completed the project. Student projects were reported through three blog posts shared on Tales from the Field, and included observations on farming practices and continuing on as a farmer after the project. Ambassadors also created best practices guides for working with specialty crops (included in the appendix), which aimed to provide useful information on specialty crop production for the next generation of farmers. Student projects ranged from a dragon fruit farm and veteran rehabilitation center to a niche market bitter melon farm catering to Asian immigrant populations. Each student presented their projects and the financial benefits of farming specialty crops at the San Diego Farm Bureau and to a diverse group of attendees. In the end, two of the six applicants did not finish the program or the required outputs. Overall the project was successful in creating four new specialty crop farmer/veterans entering the workforce and promoting the specialty crop industry to future farmers.

CND Trainings: F2F held a total of three trainings during the project in Central (Stanislaus County), Northern (Mendocino County) and Southern (San Diego County) California. The trainings were held in those locations with the goal of representing as much of the state as possible and highlighting outstanding farm to school programs. Each training had a slightly different emphasis based on the CND leading the training, but all aimed to increase California specialty crop marketability and consumption among school aged children. The agenda of each training was developed by F2F staff in coordination with the CND. Relevant materials were also developed and compiled to provide to participants at the trainings.

The first training took place in Central California by Turlock Unified School District's CND. The CND discussed his journey into procuring locally for his school meal program. The training brought out 14 dedicated school food service staff. The CND described the process of how he developed his school food marketing brand, *real.fresh*, targeting students to take part in school meals and increase fresh fruits and vegetable consumption. The CND also talked about his heavy reliance on the Department of Defense Fresh Fruit and Vegetable program to enable the purchase of local, fresh fruits and vegetables. A portion of the training was reserved to discuss his involvement in the United States Department of Agriculture pilot project for unprocessed fruits and vegetables, which allows him additional flexibility to purchase fresh fruits and vegetables from local producers.

The second training was held in Fort Bragg in Northern California by Fort Bragg Unified School District's CND. The CND discussed the challenges of being a small, remote district without a lot of agriculture in the area. To address this barrier, the CND utilized a local food hub as well as purchased from the school gardens to support the program. There were 11 attendees from school districts throughout the area, some coming as far as Trinity and Plumas County.

The third training was held in Encinitas in Southern California by Encinitas Union School District's CND. The CND discussed the process of how she converted the entire menu to scratch/fast scratch items, eliminating all packaged and highly processed products. The CND talked about working closely with the director at Farm Lab to incorporate the produce into school meals on a daily basis. Encinitas Union School District's Farm Lab is the first school-district owned, certified organic production farm supplying its own school lunch program in the nation. The CND's discussed how they incorporated nutrition education into the program at Encinitas. There were 17 child nutrition staff in attendance at the CND training in Encinitas.

For each of the trainings, the CFM was highlighted in a 30 minute presentation. The presentation focused on the purpose of the CFM, how to sign up, and how to utilize the CFM to build or strengthen their farm to school program. Many of the participants commented on what a great resource the CFM is. One such comment was from a school food service director in Central California "[I] Very much appreciate the explanation of the Marketplace. I intend to use this more regularly now that I'm more aware of what kind of searches can be done."

Overall the CND trainings enabled F2F to reach 351,228 potential students through participating food service directors as well as other relevant nutrition and school staff. Though some schools were unable to attend at the last minute, materials, PowerPoints and other resources were provided to them through email, reaching an additional 63,314 students for a total of 414,542 potential students impacted by the CND trainings. General feedback received about the training was very positive. Many others commented on all the useful, tangible takeaways that they can implement in their school food service operation to advance their farm to school activities.

Mobile Farm: F2F staff developed the scope of work for the design of the Mobile Farm. F2F staff participated in several meetings, as well as numerous emails with the contractor detailing the specifics of the vehicle and displays. The final draft was received on March 30, 2017 which provided details for the design and specific set-up of the vehicle and exhibited as well as materials needs, their approximate dimensions, and cost (see appendix). This design will eventually be able to provide an opportunity for California students without access to school gardens or exposure at home to learn about specialty crops. They will learn about how they are grown, encourage students to eat fruits and vegetables, and teach them to become lifelong consumers of California specialty crops.

The project did not benefit commodities other than California specialty crops. Project staff worked to ensure that only specialty crops were represented in all data, resources, blog posts, curriculum, tours, and CND training content.

CND Trainings: F2F staff coordinated in advance with all site hosts to discuss specialty crop priorities and to profile group attendees, in order to tailor training content. F2F staff helped the various school food service directors prepare the outline for the day of the training as well as go over the content of their presentation to ensure it was solely discussing specialty crops and the work they have done to promote them, i.e. marketing, school gardens, nutrition education, etc. Much of the coordination to the various school sites were set up and coordinated by the school food service directors in their respective districts.

Mobile Farm: The contractor was awarded the bid for the design of the Mobile Farm. The contractor has worked with various agricultural industry partners as well as technology companies. They developed and presented the detailed design of the Mobile Farm.

Ambassador Program: Archi's Institute for Sustainable Agriculture acted as the host organization for a group of Ambassadors. The organization advertised the opportunities to students and helped select the finalists. They also worked directly with students to ensure deadlines were met and specialty crops were solely represented in their projects throughout their duration.

Goals and Outcomes Achieved

The overall objective was to increase specialty crop consumption and marketability among school aged children and the general public. Activities focused on engaging students on specialty crop awareness and nutrition education, and improving access to specialty crops for children through the meals they receive at school. The performance goals established to assess whether the objectives were achieved were: (1) Increase in specialty crop direct farmer/food service director purchases and specialty crop school lunch procurement in California public schools; (2) Increase the number of specialty crop farmers and school districts registered on the CFM; and (3) Increase sales of specialty crop in school lunch programs as measured by targeted districts in California.

F2F staff worked to increase the number of schools registered on CFM, specialty crop direct farmer/food service director purchases and specialty crop school lunch procurement in California public schools through the CND Trainings.

The CND Trainings aimed to increase procurement and demand for California grown specialty crops by learning from their peers. The trainings were completed during the project in Northern, Central, and Southern California. The tours were held in those locations to highlight CNDs who have strong farm to school programs as well as with the goal of reaching a diverse set of CNDs throughout the state. The Central California training in Turlock Unified School District's CND focused on procurement and marketing of California grown specialty crops. During the training, attendees visited Turlock Unified School District's current central kitchen as well as their new central kitchen to better understand how schools can directly support specialty crops growers and can simultaneously help expose children to different types of specialty crops and teach them the benefit of consuming specialty crops.

The Northern California training that took place in Fort Bragg Unified School Districts CND focused on overcoming the challenges of a remote school district and procurement of specialty crops directly from their school gardens. The training showed other CNDs different avenues for procuring local specialty crops in less agriculturally rich regions in California. Attendees learned about the history of the farm to school program at Fort Bragg Unified School District and the challenges they faced. They then visited several of the school gardens and education centers and talked with the garden coordinator about how they created and funded a full time school garden coordinator position to sustain the work.

The training in Southern California hosted by the CND at Encinitas Union School District, focused on exposing other CNDs to fast scratch cooking using local specialty crops. Emphasis was also placed on how to purchase California grown produce during its peak ripeness, and often lowest cost, and process and preserve it for use during the school year. Attendees also visited the Farm Lab where the lettuce for the districts numerous salad bars are grown.

With the specialty crop ambassadors, the F2F supported specialty crop outreach and education. Each of the ambassadors chronicled their experiences through three blog posts each that were posted as part of the web-based stories of specialty crop engagement. The specialty crop ambassadors were a great success, as they showed benefits of growing fruits and vegetables.

F2F staff posted 21 blogs on specialty crop engagement, ranging from the stories told by the specialty crop Ambassadors to the details of each CND trainings. The blog posts helped expose the general public to the

individual experiences within each of the grant projects. The ambassadors also created best practices guides and performed outreach event promoting the benefits of farming specialty crops.

The Mobile Farm project will increase farm to school activities in the future. During this project, F2F staff worked with the contractor for the design of the Mobile Farm.

Many of the projects in this grant were only recently completed so it is too soon to measure their full effect. For example, the CND Trainings were completed in spring 2017, so their effects are still unfolding. CNDs that learned about the CFM have only had a few months in the middle of the school year to explore that resource. Therefore, the true measures of the project's effects are long term and many of the connections made and lesson learned in this grant will take time to come to full fruition.

This project sought to increase specialty crops consumption and marketability among school aged children and the general public. The activities completed showed increased specialty crops consumption and marketability among the target population. This was accomplished by reaching out to CNDs throughout California to educate them about how they can successfully incorporate California grown specialty crops into their school meals. The specialty crop ambassadors all conducted outreach events in their communities to engage consumers and promote direct specialty crop farm to consumer sales and the opportunities of farming specialty crops. The design of the Mobile Farm was completed and aimed to maximize youth engagement with agriculture. It is expected that as time goes by, this new information obtained and connections made will create even more direct sales of specialty crops to school-age children and the general public.

Performance Measure and Target: Increase specialty crop farmers registered on CFM by 20%.
Benchmark: Baseline data collected from the CFM and as of September 30, 2015, there were 30 specialty crop farmers registered on the site www.cafarmermarketplace.com.
Outcome: Sixety-three specialty crop farmers registered, 110% increase from the baseline. As school districts increase their demand for California specialty crop as a result of the CND trainings, more specialty crop farmers are expected to register on the CFM to meet that demand.

Performance Measure and Target: Increase the number of school districts registered on the CFM by 20%.
Benchmark: Baseline data from September 30, 2015 showed seven districts registered on the Marketplace including Pittsburg, Ventura, Fresno, and Natomas Unified.
Outcome: Eighty school districts registered, 1,043% increase from baseline.

Performance Measure and Target: Increase sales of specialty crops in school lunch programs by 10% as measured by targeted districts in California.
Benchmark: Targeted school districts will use benchmark data of the 2014/15 school year for specialty crop procurement.
Outcome: From the reported results of the survey, Santa Clara Unified increased their purchasing of local California produce from $200,000 in 2015/16 to $250,000 for 2016/17 school year, a 25% increase. From the Fort Bragg area, Klamath Trinity Joint Unified School District went from spending $10,000 in 2015/16 on local specialty crops to $25,000 for the 2016/17 school year, an increase of 150%. In southern California Oxnard Union High School went from spending $200,000 in 2015/16 to $300,000 in 2016/17, a 50% increase.

It was difficult for school food service directors to report on the 2014/15 school year purchasing of specialty crops since the CND trainings took place late 2016/2017 school year, project staff used 2015/16 school year as the benchmark as relevant activities for this grant did not start until the 2016/2017 school year. The schools selected as the targeted school district attended one of the CNDs, are signed up on the CFM and completed a pre-survey for the CND trainings. For central California, Santa Clara USD was used as a targeted district, Klamath Trinity Joint USD for Northern California, and Oxnard Union High School for Southern California.

Performance Measure and Target: Number of outreach events held and materials created by ambassadors.
Benchmark: Number of outreach efforts performed by ambassadors in 2014/2015 year was four events (407 individuals reached) and three blog posts per ambassador.
Outcome: Ambassadors completed three outreach events (115 individuals reached), three blog posts per ambassador and four best practices guides total (one per ambassador). Fewer individuals were reached through this project's outreach events than the previous due to the fact that the 2014/2015 year ambassadors organized their own outreach events while the current year ambassadors did three events together, thus fewer individuals were directly impacted. The ambassadors created best practices guides which will have a lasting impact and larger reach in the long run. The ambassadors also created the same number of blog posts as the previous group of students.

This project successfully increased specialty crop consumption and marketability among school age children and the general public.

Beneficiaries

CND Trainings: During the CND Trainings that took place across the state, CNDs, child nutrition specialists, and garden coordinators were taught by their peers about how they developed successful farm to school programs by expanding California specialty crops procurement, education, and marketing to school age children. School CNDs interested in incorporating local produce into school meals directly benefited from these trainings. Students and specialty crop farmers across California stand to benefit from these trainings.

Specialty Crop Ambassadors: The four specialty crop ambassadors received education that has made them equipped to become specialty crop farmers and contribute to the industry. The recipients are also now able to act as ambassadors for future specialty crop farmers. Their best practices guides can be used by individuals looking to grow specialty crops as well. The specialty crop ambassadors created projects that informed the next generation of the benefits of growing and consuming specialty crops, as well as the career opportunities therein. Outreach events reached 115 potential farmers and best practices guides are available to potential farmers.

Mobile Farm: The Mobile Farm design developed during this grant will go on to provide an opportunity for California students without access to school gardens or exposure at home to learn about the benefits of specialty crops.

Forty-two school food service personnel had the opportunity to attend the CND trainings in their region and learn from their peers how to successfully start or enhance their farm to school program by incorporating California specialty crops into their menus. Collectively these 42 school food service personnel have the potential to impact 414,542 California students.

Sixty individuals working with the San Diego Community Health Improvement Partner's Farm to School Task Force had the opportunity to learn about the CFM and how to help school food service directors connect with local farmers in their area.

3,106,462 students in California elementary schools have the potential to experience hands on learning about how specialty crops are grown and the benefits of their nutritional value. This exposure has the potential to create lifelong eaters of California specialty crops when the physical buildout of the Mobile Farm takes place. Greater awareness of resources that enable local, specialty crops purchases allows for a possible 186% return on investment in certain regions in California for money spent on local, direct market products.

Lessons Learned

The biggest lesson learned throughout the course of this project is that peer-led learning is most effective to create behavior change. By bringing together school CNDs and having them learn from their peers, they were able to see that incorporating California specialty crops is feasible, practical, and makes their meal program more successful. In addition, the peer-to-peer learning created an environment where food service staff were able to network and felt free to ask questions and generate conversations that otherwise might not take place. For example, during two of the CND trainings it came up that numerous CNDs were having issues communicating with parents. Low participation rates are often one of the issues many CNDs are up against. What wasn't as obvious was that CND's perception is that a lot is coming from parents who do not know what is being served in the cafeteria. CNDs wanted resources they could give or present to parents at PTA meetings and other school functions to let them know what is actually being served in the cafeteria and educating them on their farm to school program. Being able to educate parents on the healthy food being prepared as well as informing parents that participation from all students is important to help grow the program. This somewhat tangential conversation inspired the project staff to incorporate developing such resources for another grant supporting farm to school work.

During the grant, project staff also came to realize that certain projects are well suited for state agencies to undertake and some are better suited for private entities. The design phase of the Mobile Farm proved to be particularly challenging regarding developing contracts for such services between the state and a private company. Through this process, project staff also realized that the physical buildout of the Mobile Farm, staffing, and running of the vehicle will just not be feasible for a small office of five staff members.

The unexpected outcome was that only four ambassadors completed the program instead of six. If all six of the ambassadors would have finished, it would have increased the number of outreach events and individuals impacted through the events and best practices guides. To maximize reach the project staff suggests holding each ambassador's outreach event separately.

Additional Information

CND Trainings:

- Central California: http://blogs.cdfa.ca.gov/TalesFromTheField/?p=1093
- Northern California: http://blogs.cdfa.ca.gov/TalesFromTheField/?p=1115
- Southern California: http://blogs.cdfa.ca.gov/TalesFromTheField/?p=1157

Mobile Farm: Final design: See attachment 1.

Ambassadors: Best practices guides: See attachment 2.

CND Trainings: Handouts provided at CND trainings and through email

- Pilot Project: See attachment 3.

References

1. California Department of Education. *CalEdFacts*. 2015-2016. http://www.cde.ca.gov/ds/sd/cb/ceffingertipfacts.asp (accessed 7/25/2017)
2. Hardesty, S., Christensen, L.O., McGuire, E., Feenstra, G., Ingels, C., Much, J., Boorinakis-Harper, J., Fake, C., and S. Oneto. 2016. Economic Impact of Local Food Producers in the Sacramento Region. http://sfp.ucdavis.edu/files/238053.pdf (accessed 7/25/2017)

USDA Project No.:	Project Title:	
13	Farm-to-WIC Expansion Campaign: Increasing Redemption of WIC Produce Checks at Farmers' Markets	
Grant Recipient: California WIC Association	**Grant Agreement No.:** SCB15013	**Date Submitted:** December 2018
Recipient Contact: Karen Farley	**Telephone:** (916) 572-0700	**Email:** kfarley@calwic.org

Project Summary

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) is a federal program of the United States Department of Agriculture (USDA). In California, it is administered by the California Department of Public Health (CDPH) WIC Division, which contracts with 83 local WIC agencies to provide services to over one million limited-income families with children up to age five each month. These services include checks redeemable for specific nutritious foods, nutrition counseling, breastfeeding support, and connection to medical and social services.

The nonprofit California WIC Association (CWA), in partnership with its member local WIC agencies, community-based organizations, local farmers' markets, and CDPH WIC, accepted this grant to launch a targeted Farm-to-WIC Campaign (Farm2WIC) designed to increase the number of certified farmers' markets and small farmers who are trained and authorized to accept WIC Fruit and Vegetable Checks (FVCs) for fresh fruits and vegetables. The goal was to increase demand for and access to fresh, locally grown specialty crops by promoting higher utilization of FVCs at authorized farmers' markets, exploring the feasibility of enrolling WIC families in local Community-Supported Agriculture (CSA) systems using their FVCs, and investigating the option of mobile farmers' markets for WIC FVCs.

Since 2009, FVCs redeemable at WIC-authorized stores for almost any fresh, frozen or canned produce item have been part of the WIC food package for women and children six months and older. Most FVCs are redeemed for fresh produce at grocery stores but, in California, redemption is also allowed at certified farmers' markets. The 2014 USDA Final Rule on WIC food packages made the WIC market more accessible for small specialty crop growers by increasing the FVC value for children, adding $20 million in annual California WIC fruit and vegetable purchasing power for parents participating in WIC. This Final Rule also allowed state agencies to authorize both individual farmers and farmers' markets (via market managers) to accept the FVCs, conforming to the rules in the separate but much smaller WIC Farmers' Market Nutrition Program (FMNP) and removing a huge barrier to farmers' markets participation in FVC redemptions.

California WIC reported that over 12 million FVCs were transacted in 2012 at an annual value of $87.7 million. WIC moms and children aged one to four received a $10 and $6 FVC per month, respectively. With the 2014 USDA Final Rule, these check values increased to $11 and $8 respectively, while a $4 check was added for infants 6-12 months old.

CWA and partners aimed to leverage this huge specialty crop market opportunity and timely federal reforms to double the number of farmers/markets authorized to redeem WIC FVCs and aggressively promote the farmers' market to over a million WIC clients as an option to purchase specialty crops. Farm2WIC also strove to increase awareness and encourage availability of affordable and locally-grown specialty crops in lower-

income communities, expecting that this would increase specialty crop consumption among adults and children. Knowing that this would re-direct some of the WIC purchasing power from retail grocery outlets to California farmers' markets, another expectation was to benefit family farmers and local economies, and improve food access, nutritional health, and community cohesion for WIC families.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Project Activities

A. *Collect and analyze California WIC farmer/farmers' markets vendor authorization and FVC redemption data, using monthly, seasonal and annual data.*
CWA worked with CDPH WIC to gather data on the number of farmers and markets authorized to accept FMNP checks and FVCs, plus the value of benefits redeemed, at baseline and at each reporting period benchmark.

B. *Identify and target for technical assistance farmers' markets with high volume redemption of low-income customers using WIC and farmers' markets monthly, seasonal and annual data.*
CDPH WIC identified the markets meeting these criteria each year, which guided collaborative work to offer training and technical assistance in areas of greater need.

C. *Assess needs/interest among farmers' markets managers and other stakeholders regarding FVC option, using an online survey and conducting phone interviews.*
CWA sent a brief survey to stakeholders the first summer (2016), but response was low. As the project team continued contacting market associations, WIC farmers' market liaisons, and market managers via email and phone, it became clear that an online survey and phone interviews would not be as effective as connecting while attending in-person meetings of existing groups.

D. *Share data and information about WIC FVCs and FMNP with Farmers' Markets Associations, food policy councils, County Nutrition Action Plans, Agriculture Advisors, Farm Bureau, etc.*
CWA introduced the Farm2WIC campaign and sent an informational flyer via email to over 60 stakeholders in at least 12 counties. The flyer continues to be linked on the Farm2WIC webpage: http://calwic.org/storage/Farm2WIC/CWIC_Farmers_Mkt_Flyer_rev.pdf

E. *Inform regional, or statewide organizations who work with farmers' markets, community food access, obesity, etc. about WIC FVCs and FMNP by organizing six or presenting at least four meetings annually.*
Presented in person or remotely or exhibited at meetings of at least four organizations, including Pacific Coast Farmers' Market Association, Riverside County CalFresh and Certified Farmers' Market Managers, Central Valley Health and Nutrition Coalition, Hunger Action LA and California Small Farm Conference.

F. *Prepare outreach, training and technical materials to support farmers' markets and farmers to seek WIC vendor authorization.*
CWA developed a Farm2WIC webpage and posted materials specifically designed to assist farmers and market managers in getting authorized and marketing their status once authorized. Materials were distributed at every training, with additional copies shipped upon request at no cost to farmers or market managers: postcard; market entry sandwich board sign; market managers banner; farmers' booth sign;

WIC participant flyer; WIC staff flyer/info sheet.
http://calwic.org/focus-areas/engaging-wic-families/farm2wic

G. *Launch Statewide Campaign at Annual WIC Conference.*
At CWA's 2017 and 2018 Annual Conferences in San Diego, CWA hosted a Farm2WIC booth in the Trade Show and workshops related to specialty crop access at farmers' markets. These were key opportunities to educate WIC staff about Farm2WIC and strategies and opportunities to promote Farm2WIC among the families they serve.

California's version of The Farmers' Market Cookbook, developed by CWA with the publisher, Nutrition Matters, debuted at the 2018 Conference with pre-publication samples provided. CWA distributed over 73,000 cookbooks (63 percent in English, 37 percent in Spanish) at no cost to 55 local WIC agencies in May. Five agencies purchased 4,426 more cookbooks in June directly from the publisher.
http://stores.numatters.com/farmers-market-book-california-special-edition/

H. *Test Feasibility of using FVCs at CSAs with 3 farmers.*
The idea to test CSA boxes was not able to be developed.

I. *Provide technical assistance to farmers' markets and farmers for WIC FVC and FMNP.*
CWA co-hosted live training sessions with CDPH WIC in 11 locations statewide, providing registration services, education and marketing materials, and helping to answer questions on-site and by phone.

J. *Use traditional and social media advocacy to create "buzz" about the Campaign throughout California.*
Regular articles in the CWA Flash biweekly e-newsletter (4,391 subscribers), WIC Watch magazine (online and over 2,000 print copies mailed), and WIC Director Updates (over 90 subscribers), plus periodic posts on Facebook (1,947 followers) and Twitter (1,693 followers), reached California readers as well as a diverse national audience.

In all communications, CWA staff linked to the Farm2WIC webpage which has enjoyed 1,377 unique visitors since its inception (April 2017), or an average of over 90 visitors per month.
http://calwic.org/focus-areas/engaging-wic-families/farm2wic

K. *Pilot using WIC FVCs at CSAs in California with 3 farmers.*
The idea to test CSA boxes was not able to be developed.

L. *Publish Policy Brief and Toolkit to help California communities grow Farm-to-WIC model and encourage national expansion.*
CWA published "Farm2WIC: Tapping New Markets, Building Healthy Communities" (June 2018), an issue brief addressing the challenges and recommended solutions to increasing access among WIC families to specialty crops at farmers' markets. Print versions were provided to CDPH WIC leadership and distributed to State Legislative representatives during Education Day visits in November and at future CWA conferences. To promote national expansion of FVC redemption for specialty crops at farmers' markets, the online version will be shared widely through CWA communication channels and print copies will be distributed to Congressional Representatives during the 2019 National WIC Association Leadership Conference. The online version is available at

http://www.calwic.org/storage/documents/reports/2018/Farm2WIC_Poilicy_Brief_7WEB.pdf.

CWA published "Farm2WIC Toolkit: Connecting Farmers, Market Managers, Local WIC Agencies & Partners with Families for Vibrant Markets and Healthy Communities" (June 2018) describing best practices for authorized farmers and farmers' markets to accept FVCs and engage families around using WIC checks at the farmers' markets. The Toolkit also includes resources and tips for local WIC agencies to successfully educate participating families about the opportunity to use FVCs and FMNP checks at markets. Print versions were mailed to 70 farmers and market managers who attended Farm2WIC training in 2018, plus all 83 local WIC agencies, and included samples of education and marketing materials. CWA and CDPH WIC will continue to distribute it to farmers and market managers at training workshops through 2019. The online version is available at http://www.calwic.org/storage/Farm2WIC/Farm2WIC_Toolkit7WEB_FINAL.pdf.

The project only focused on benefitting specialty crops.

The significant contributions and role of project partners in the project:
CDPH WIC: As a statewide association for local WIC programs, CWA has a 20-year history of a close working partnership with CDPH WIC, the state agency responsible for authorizing and training all vendors, including farmers and farmers' market managers. CDPH WIC staff with expertise in farmers' markets continue to handle all new applications and train and monitor all authorized farm vendors. CWA partnered with CDPH WIC to ensure that Farm2WIC strategies and messages are closely coordinated with state agency calendars and priorities. At grant's end, CWA and member local WIC agencies will continue to promote and support farmers' market use of FVCs to increase specialty crop purchase and consumption.

Local WIC Agencies, while not named as partners in the grant, helped host FVC-authorization training events and contributed to successful development and implementation of Farm2WIC in many ways.

Some examples:
- Glenn County WIC Program: reviewed translations and field-tested materials
- Merced County Community Action Agency WIC Program: translated customizable flyers from the Produce for Better Health Foundation, now available on the CWA website in English and Spanish http://pbhfoundation.org/pdfs/pub_sec/st_coor/mar_tools/WIC_09/FACTS_TIPS1_FINAL.pdf
- Public Health Foundation Enterprises WIC Program (a local WIC agency in Los Angeles): contributed ideas for and reviewed materials, developed strategies featured in the Policy Brief
- Riverside Public Health System WIC Program: Hosted a training/meeting, translated and field-tested materials
- Trinity County WIC Program: contributed ideas for and reviewed materials

Other partners, also not named as partners in the grant, helped in significant ways:
- California Food Policy Advocates (CFPA): strategized ways to increase access to specialty crops for low-resource families; collaborated with CWA to present a webinar and conference workshop on same topic
- Urban & Environmental Policy Institute at Occidental College (Oxy): shared best practices and information used to increase use of public benefits at farmers' markets, reviewed an early draft of the Toolkit

- Pacific Coast Farmers' Market Association: contributed ideas for Farm2WIC campaign development and strategized around banking challenges

Goals and Outcomes Achieved

The workplan activities described above were completed to achieve the goals. The activities included identifying stakeholders in the farming, farmers' market and hunger prevention communities; establishing outreach activities; developing, testing and employing marketing materials; providing training and technical assistance opportunities; and establishing strong collaborative relationships with state WIC staff who oversee WIC FVCs and farmers' markets.

The number of authorized farmers and markets far exceeded the goal. While the proposal stated the number of authorized markets would double from 35 to 70, baseline was only 9. Thus, the increase to 295 FVC-authorized markets (462 total) was astounding. In contrast, the number of FVC redemptions was much higher at baseline, yet there was a steady increase in redemptions every year. While each month varies just as a farm output does, comparing redemptions in June 2016 (862), June 2017 (1,303), and June 2018 (1,646) shows steady growth despite declining WIC participation.

Outcome Measure	Baseline (Oct. 2015)	Final (June 2018)
Participating farmers' markets; goal: double, from 35 to 70	54*	462 total (295 FVC)
WIC authorized farmers; goal: double, from 150 to 300	77	965 total (161 FVC)

*Earlier CWA erroneously reported there were nine participating markets at baseline; this is the correct number recently verified by CDPH WIC.

	2015 (Baseline)	2016	2017	2018 (Final)
Outcome Measure	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Jun**
WIC FVC redemptions at farmers' markets: goal: double, from 5,000* to 10,000/year	14,131	11,868	12,071	5,097

*The goal of 5,000 was set when the grant proposal was initially written in 2010. By the time it was funded, redemptions were much higher.

Major successful outcomes of the project:
The number of authorized farmers and markets far exceeded the goal. While the proposal stated the number of authorized markets would double from 35 to 70, the more than five-fold increase from 54 to 295 FVC-authorized markets (462 total) was astounding. The number of authorized individual farmers more than doubled.

In contrast, the number of FVC redemptions was much higher at baseline (2015), when WIC participation totaled nearly 1.4 million statewide. Despite the drop-in participation — only 1,002,632 — there was a steady

increase in redemptions from 2016 to 2017. While each month varies just as a farm output does, comparing redemptions in June 2016 (862), June 2017 (1,303), and June 2018 (1,646) shows steady growth despite declining WIC participation.

Beneficiaries

- Farmers' market associations and managers processed more FVCs for specialty crops and gained a greater customer base by welcoming WIC customers.
- Growers and market vendors gained income from FVCs and additional cash purchases that they likely would not have had otherwise.
- Low-income families gained access to healthy produce and farmers' markets.
- Local agency and state WIC staff gained a better understanding of how to collaborate with farmers' markets and strategies for assisting families in accessing specialty crops.
- Local nutrition and hunger organizations — such as Hunger Action LA, Oxy and CFPA — gained collaborative support in achieving their goals to improve access to healthy foods, especially fresh produce for low-income families who are at higher risk for chronic disease.

In 2015, 2016 and 2017, respectively, FVC redemptions provided $120,896, $102,666 and $104,649 in specialty crop grower income. Given the value of redemptions during the first half of 2018 ($43,660) and the greater redemption rates CDPH WIC anticipates in the second half of 2018, CWA expects the economic impact to only increase over time for the 295 markets and 161 farmers accepting FVCs.

As of June 30, 2018, WIC participation was 1,002,632 women, infants and children statewide. Most of these participants receive a FVC each month, so the economic potential for these families remains significant.

Lessons Learned

Positive:

- Growers want to benefit their community as well as generate revenue, so they accept FVCs despite the additional work it takes to process/redeem checks.
- Offering meetings/trainings on Mondays or Tuesdays helped support busy growers and market managers.
- Farmers and market managers were both interested to become FVC certified.
- Some WIC agencies established other opportunities for families to also get CalFresh produce benefits in conjunction with provision of WIC FVCs at farmers' markets.
- State WIC leadership was very supportive of the collaboration with farmers' markets.

Negative:

- Due to factors beyond control, especially low birth rates, WIC participation declined significantly during the grant period, impacting outcome measures such as FVC redemptions.
- Connecting with market associations and local partners was challenging, sometimes unsuccessful.

Unfortunately, some major and cumulative project interventions, including training & marketing in early 2018, did not have enough time to show the full impact by the end of the grant period.

Connecting with market associations and local partners, when possible, led to other collaboration opportunities, such as reviewing the report by Oxy, "Promoting Farmers' Markets in Los Angeles"

https://www.oxy.edu/sites/default/files/assets/UEPI/Market%20Together%20Research%20Report%20FINAL.pdf and co-hosting a workshop & webinar with CFPA.

A Public Health Nutritionist at the Indiana State Department of Health Division of Nutrition and Physical Activity asked to adapt the Farm2WIC materials for their own use; CWA granted permission.

When developing the grant, it appeared use of WIC benefits for purchase of CSA boxes of specialty crops would be allowable, in addition to purchases at farmers' markets. During the grant period, WIC beneficiary transactions did not allow for CSA boxes, but only for farmers' markets transactions, for specialty crop purchases.

Additional Information

WIC & CalFresh: Better Together – link to webinar materials, explain collaboration at local and state levels (or under Lessons Learned/unexpected outcomes, above)
https://cfpa.net/webinar-materials-calfresh-wic-better-together/

USDA Project No.:	Project Title:	
14	Effects of California Dried Plums on Bone and Cardiovascular Health	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB15014	**Date Submitted:** December 2017
Recipient Contact: Dr. Robert Hackman	**Telephone:** (530) 752-4004	**Email:** rmhackman@ucdavis.edu

Project Summary

Postmenopausal women are at-risk for developing osteoporosis and cardiovascular disease due to cessation of ovarian hormone production. Certain nutritional approaches can reduce the risk and debilitating effects of these chronic diseases. The consumption of dried plums has been reported to provide some bone health benefits in a limited number of animal models, an observation that has been supported by select in vitro models. As a prelude to a potential long-term feeding trial with dried plums in postmenopausal women, this project examined the effects of short-term dried plum consumption at low and typical levels of dried plum intake. Determining if dried plums (Prunus domestica L.) could help prevent bone loss and reduce cardiovascular disease risk would likely increase market demand nationally and worldwide, and improve the health of Californians.

The aging of the United States population has presented a number of challenges, many of which could be addressed through nutritional approaches. Postmenopausal women are particularly at-risk for a number of chronic diseases such as osteoporosis and cardiovascular disease, primarily due to cessation of ovarian hormone production. By 2020 it is estimated that 50 percent of women at 50 years and older will either suffer from or be at-risk of bone loss, and cardiovascular disease is expected to grow to more than 23.6 million by 2030. Dietary strategies, including targeting specific types of food, will be important to address health issues, now and in the future.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The project team sought to study the effects of short-term dried consumption at low and typical levels of dried plum intake on 1) C-telopeptide, beta-cross-linked (CTX), a marker of bone resorption; 2) microvascular function as assessed by peripheral artery tonometry (PAT), and 3) changes in colonic fermentation products (breath hydrogen and methane). Twenty-seven healthy, postmenopausal women were randomly assigned to consume either six dried plums (approximately 42 grams) or two dried plums (approximately 14 grams) per day for two weeks (first half). This was followed by a two week washout period and then crossed over to the other group for two weeks (second half). No significant differences were noted between the six dried plums and the two dried plum treatments with respect to changes in CTX, in two calculated indices of PAT (Reactive Hyperemia Index [RHI] or Framingham RHI), or in breath measures. Similarly, no treatment by half interaction was observed for any of the variables. However, the changes in CTX in the first half (increased in both groups) differed significantly from the second half (no change or decline; $F = 9.26$, $P = 0.006$). The results did not support the hypothesis that short-term intakes of dried plums would provide positive effects on biomarkers of bone resorption in postmenopausal women. However, the trend of a

possible response to treatment was noteworthy, and suggested that a follow-up study with a longer duration of feeding would be warranted.

Media inquiries and sales data (from the California Dried Plum Board) will be monitored for the next three years.

This project solely enhanced the competiveness of specialty crops. All project expenditures were tracked and monitored by the accounting department.

The California Dried Plum Board provided an additional $2,300 in unrestricted funds. These funds were used to purchase breath collection bags and supplies, which were then assessed for breath hydrogen and methane, two measures of intestinal fermentation products. The Executive Director of the California Dried Plum Board, along with the science consultant, attended a meeting at University of California, Davis with the researchers.

Goals and Outcomes Achieved

After completing contract arrangements and obtaining approval to conduct a human study from the University of California, Davis Institutional Review Board, supplies were ordered and staff training was completed. Dried plums were divided into the necessary amounts. Advertising in local newspapers was conducted, and the recruitment of volunteers was commenced. The intervention was conducted and once all participants completed their involvement, data processing and statistical analyses was begun. Following interpretation of the data, an abstract was submitted and accepted for the Eighth International Conference on Polyphenols and Health, Quebec, October 2017. There were approximately 200 people in attendance from over 20 different countries.

The goal of the project was to evaluate the effects of dried plum intake on measures of vascular function and markers of bone health in postmenopausal women. This pilot study was proposed to determine if a short-term study would be a suitable alternative to a longer term, more expensive approach to assessing bone health in postmenopausal women. All tasks were accomplished, including the results showing that a two week intake period, followed by a two week washout and then another two week intake period, did not result in significant changes in markers of bone resorption, blood flow, or breath measures. However, a strong trend was noted for the bone biomarker, suggesting that a longer duration of intake might result in a more favorable outcome.

A total of 121 women volunteered for the study, of which 74 were excluded because they did not meet the eligibility criteria. The remaining 47 women were screened for normal clinical chemistry levels, of which 20 were excluded. The remaining 27 women were enrolled in the study. The University of California, Davis Pathology laboratory was unable to use three blood samples, so only data from 24 women was included in the CTX analysis. Blood flow values from six of the 27 women enrolled in the study were excluded from the final analysis due to insufficient integrity of readings from the analytical equipment.

Based on the pre-study power calculations, the required number of participants completed the study. The most significant finding of the project was the suggestion that the bone resorption biomarker was trending in a favorable direction by the end of the six week intervention. Insights into future study design were also obtained. A manuscript about the study is planned to be submitted to a nutrition science journal in early 2018.

Beneficiaries

As noted above, the first introduction of the results in the public domain was in October 2017. The 27 participants in the study benefitted directly from the project.

Efforts to better understand the health benefits of California dried plums will enable informed health messages and ultimately lead to an increase in dried plum demand, which would benefit the 900 dried plum growers and 25 dried plum packers in California.

Lessons Learned

The project proposed that short term intake of low or normal amounts of dried plums could favorably affect biomarkers of bone and vascular health. The outcomes did not support this idea directly, as no statistically significant changes were noted for either amount of dried plum intake. However, a clear trend toward improvement in the bone biomarker was noted. The results of this study will play an important role in informing a research strategy moving forward (i.e. conducting a long term study, greater than 12 months).

Recruitment was done primarily by newspaper advertisements in the Sacramento, Davis and Woodland papers. While this was cost effective, newer, more targeted methods are now available through social media and newspaper e-mailing lists. Future recruitment through these electronic methods may provide a more cost effective method of recruitment.

The most important lesson learned from this project was that a two or even six week feeding period was not sufficient to detect significant changes in markers of bone or vascular health in postmenopausal women. Further, the crossover design with a washout period (two weeks on; two weeks off; two weeks on) should not be repeated, as it was unclear if a true “washout” occurred after the first feeding period. The gut microbiome may have influenced the measurements in the second two week feeding period, which was unknown at the start of the study. The lessons learned from this project thus suggested that a longer intervention, and at a higher intake of dried plums than was used in this project, would be useful. Further, other markers of bone health, such as indices of bone formation in addition to bone resorption, would be important to assess.

All studies on dried plums and bone health to date were focused on postmenopausal women, whom are at the most risk for bone loss. However, premenopausal and perimenopausal women are also losing bone, albeit at a different rate compared to postmenopausal women. Future studies exploring the role of dried plums in premenopausal women, assessing both bone resorption and bone formation, would provide new insights that have yet to be determined. A study on premenopausal women, if results are favorable, would likely open a new market for the sale of dried plums to a group that has not yet been targeted with bone health messages.

No unexpected outcomes were noted, beyond the results described above.

Additional Information

No additional information.

USDA Project No.: 15	Project Title: Lettuce Cultivars with Improved Salad Processing Efficiency	
Grant Recipient: United States Department of Agriculture, Agricultural Research Service	**Grant Agreement No.:** SCB15015	**Date Submitted:** December 2018
Recipient Contact: Beiquan Mou	**Telephone:** (831) 596-5088	**Email:** Beiquan.Mou@ars.usda.gov

Project Summary

Lettuce is widely used in packaged salads. Fresh-cut lettuce can have short shelf life and deterioration can occur within a week after processing. Deteriorated lettuce is not marketable, must be disposed, and results in the need for more lettuce to be grown, processed, and transported. Tissue deterioration is also detrimental to the nutritional quality of salad. Lettuce accessions with extended shelf life and good nutrition retention will help reduce waste and increase efficiency. The objectives of the project were to identify lettuce accessions, gene, or gene combinations that provide good shelf life and increase yield stability, and to determine the correlation between shelf life and nutrient retention.

Packaged salads are becoming more popular and production of lettuce in California has been increasing. Good shelf life, yield stability, and high nutrient retention are vital for lettuce production and consumption. Improved shelf life and yield stability in lettuce will help decrease salad waste and improve packaged salad distribution. Lettuce accessions identified in the project as having good shelf life will be used in breeding for better shelf life. Similarly, accessions identified with good yield stability or good nutrition retention will be employed for breeding advanced lettuce cultivars. Genetic markers determined to be associated with the above-mentioned traits can be used for marker assisted lettuce breeding.

Genome-wide association studies (GWAS) is a new and faster approach for genetic analysis to identify genes associated with traits. GWAS is performed in a genetically diverse population. The population of lettuce accessions developed in this project will be available for GWAS of any trait in lettuce. The genotypic data produced will serve for genetic analyses of other traits.

The project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Four hundred and ninety-eight lettuce accessions were selected for the study of shelf life in salad-cut lettuce. Small quantity of seeds (1–10g) were produced in the greenhouse for the lettuce accessions. The seeds were cleaned, weighed, and catalogued. Seeds of each accession were mailed to seed companies to increase seeds in the Central Valley of California in April 2016. Seeds for 463 lettuce accessions were harvested in July to September of 2016. Seeds were dried and cleaned, and seed weight was recorded. Seeds for each accession were stored in envelopes as working stock and remaining seeds were stored in paper bags for long-term storage. Remaining accessions were increased in the green house in 2016 and 2017.

Seed samples of the lettuce accessions were submitted for tunable Genotyping by Sequencing (tGBS®), where DNA extraction, genotyping, and single-nucleotide polymorphism (SNP) calling were performed. SNP data for

the accessions was used for performing genetic diversity analysis and GWAS for shelf life and yield stability. Genetic diversity analyses included population structure, principal coordinate analysis, and phylogeny.

In August 2016, the late season experiment was planted in the United States Department of Agriculture's (USDA), Spence Farm located in Salinas, California. In November 2016, lettuce heads were harvested, processed into salad, and evaluated on weekly intervals for salad tissue deterioration. Data from salad evaluation were used as phenotypic trait and combined with genotypic data to perform GWAS. Significant marker-trait association (SMTA) was detected on chromosome four indicating a genetic region associated with variation in shelf life. The results from 2016 late-season experiment were presented in American Society for Horticultural Science annual conference 2017 in Waikoloa, Hawaii.

In March 2017, seeds of 498 lettuce accessions were planted in a local grower's field in Marina, California for the early-season experiment. Field plots were harvested, processed into salad, and evaluated on weekly intervals for tissue decay. For the first mid-season experiment, 498 lettuce accessions were planted in USDA's Spence Farm in May 2017 and harvested in August 2017. The second mid-season experiment was planted in a grower's field in Gonzales, California in June 2017 and harvested in September 2017. Plants from harvests were processed into salad and evaluated on weekly intervals for at least six weeks. From the Spence Farm, 50 accessions were harvested in three replications for nutrient analyses. Salad samples were submitted on the first and third week of harvest for Vitamin A (beta carotene) and sugar analyses. Vitamin C (ascorbic acid) analysis was performed on the samples during the first, second, and third week of processing in the USDA-Agricultural Research Service (ARS) lab.

For another nutrient analysis experiment, three replications of 50 accessions were planted at the Spence Farm (Salinas, California) in August 2017. They were harvested and processed in November 2017 for Vitamin A, Vitamin C, and sugar profile analyses. Salad samples were submitted to a lab during the first and third week of harvest for Vitamin A and sugar analyses. Vitamin C analysis was performed on the samples during the first, second, and third week of processing in the USDA-ARS lab.

Shelf life data and yield data of 498 lettuce accessions from four experiments from different locations (Marina, Spence, and Gonzales) were analyzed as well as data from nutrient analyses (Vitamin A, Vitamin C, sugar profile). Yield stability coefficients were calculated and statistical analyses were performed. GWAS were performed for shelf life, shelf-life stability, yield, and yield stability. Statistical analysis for correlation of salad decay and nutrition retention was performed. Calculation and analysis of shelf-life and shelf-life stability coefficients identified lettuce accessions that remained fresh longer and had good shelf-life stability. In general, vitamin C level decreased with the increase in salad deterioration. Vitamin A and sugar data will be analyzed statistically to identify their relationship with salad decay. Original nutrient contents were specific to lettuce accession.

This project focused solely on lettuce to enhance the competitiveness of this important specialty crop.

A vegetable seed company helped project staff grow and increase seeds of 470 lettuce accessions in the Central Valley in 2016. A farm provided land for the project in Marina, California, to plant 498 lettuce accessions in March 2017 for the early-season experiment. Another farm provided land for the project in Gonzales, California, to plant 498 lettuce accessions in June 2017 for the mid-season experiment.

Goals and Outcomes Achieved

A diversity panel of 498 lettuce accessions was selected for GWAS. Seeds were harvested from single plants of each accession in greenhouse which were used to increase seeds in field in Central Valley. Seeds harvested from field were dried and cleaned, and seed weight was recorded. Seeds for each accession were stored in envelopes as working stock and remaining seeds were stored in paper bags for long-term storage. These activities contribute to the goals in the Expected Measurable Outcomes: 1) Develop a new genetic resource for use in association mapping, a method that is faster than previous methods of genetic analysis.

Four hundred and ninety-eight lettuce accessions were evaluated in different seasons and environments for shelf life and yield. Nutrient analyses (Vitamin A, Vitamin C, sugar profile) were performed on 50 accessions in two experiments at different times of storage to assess original nutrient content and relatedness of shelf life and nutrient retention post processing. Shelf life data, yield data, and nutrient data were analyzed, and genome-wide association studies were performed. Results from those evaluations contribute to Expected Measurable Outcomes: 2) Identify cultivars that can routinely remain saleable as salad-cut lettuce for more than 20 days; and 3) Generate new knowledge regarding cultivar shelf life and nutrient retention.

Seeds for about 498 lettuce accessions were bulk increased in field or greenhouse. This population can serve as a genetic resource for association studies of any other trait in lettuce. Seeds will be made publicly available as needed.

A lab performed tGBS® on the lettuce accessions. This genotypic data will be a great resource that can be used in future for any genetic analysis of these accessions.

The population has already been phenotypically evaluated and analyzed for some other traits including bolting stage, resistance to tip burn, downy mildew, Impatiens necrotic spot virus (INSV), and lettuce drop (caused by *Sclerotinia*).

The goals established for this project were to 1) Develop a new genetic resource for use in association mapping, a method that is faster than previous methods of genetic analysis; 2) Identify cultivars that can routinely remain saleable as salad-cut lettuce for more than 20 days; and 3) Generate new knowledge regarding cultivar shelf life and nutrient retention.

Regarding the goal to develop a new genetic resource, diverse population of lettuce accessions (cultivars, breeding lines, and plant introductions) were selected and seeds were increased in bulk in greenhouse and field. The whole population was genotyped with tGBS®, this data can be used in genetic analysis. This population of 498 lettuce accessions can be used as a genetic resource for association mapping of any trait in lettuce. SMTA was detected on chromosome four indicating a genetic region associated with variation in shelf life.

The second goal was to identify lettuce cultivars that remain fresh enough as salad-cut lettuce for three weeks or more. Four field experiments were performed during 2016 and 2017 to evaluate salad decay every week after processing for at least six weeks. Calculation and analysis of shelf-life and shelf-life stability coefficients identified lettuce accessions that remained fresh longer and had good shelf-life stability. Yield stability coefficients were calculated and statistical analyses were performed. GWAS using tGBS® data was performed for shelf life, yield, yield stability, and shelf-life stability to determine QTL locations of all the traits.

For the third goal to generate new knowledge regarding cultivar shelf life and nutrient retention, 50 lettuce accessions were evaluated for nutrients including Vitamin C (ascorbic acid), Vitamin A (beta carotene), and sugar profile. The 50 accessions had diversity in shelf life based on 2016 late-season experiment. In two experiments in 2017, salad samples were analyzed at different times of storage to assess original nutrient content and relatedness of shelf life and nutrient retention post processing. Correlation study for salad decay and nutrient retention was performed. In general, nutrient level decreased with the increase in salad deterioration. Original nutrient contents were specific to lettuce accession. Statistical analyses for most of the nutrient contents have been performed. GWAS was performed on original nutrient contents as well as nutrient retention.

The results from the project were presented in American Society for Horticultural Science (ASHS) annual conference 2017 in Waikoloa, Hawaii, and in American Society of Plant Biologist (ASPB) annual conference 2018 in Montreal, Canada.

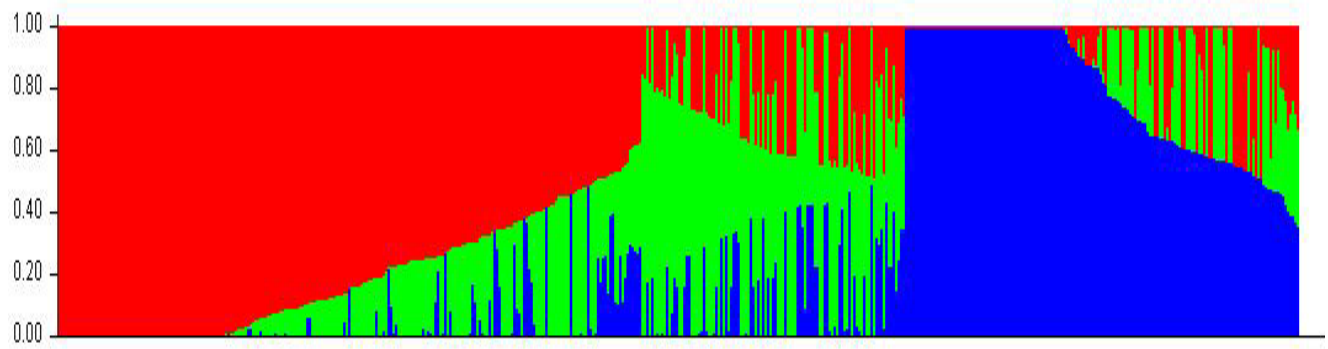


Figure 1. Population structure of 494 lettuce accessions based on 897 SNPs implemented in program STRUCTURE at $K = 3$. Red, blue, and green colors represent the three subpopulations.

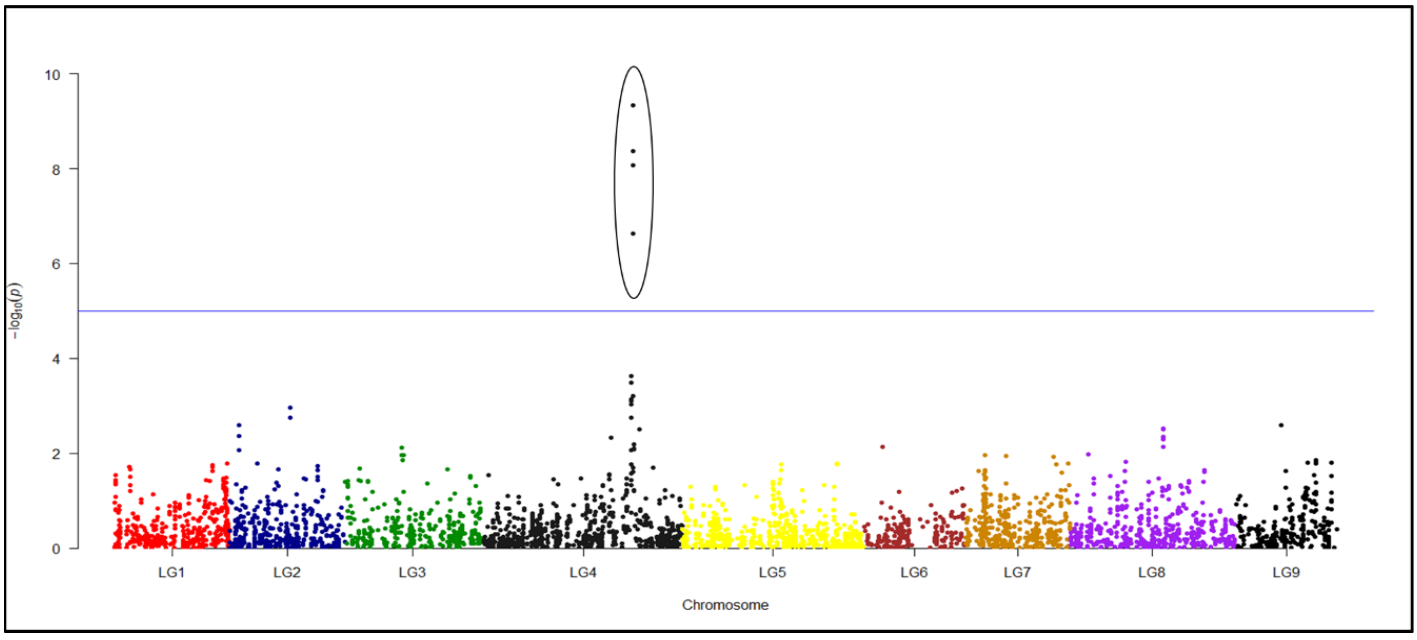


Figure 2. Genome-wide association study for shelf life of 493 lettuce accessions from four field experiments (three locations in years 2016 and 2017) showed significant marker-trait association on chromosome four. The above Manhattan plot was created using mean AUDePS (area under deterioration progress curve) calculated for each accession at week five after salad processing. AUDePS was calculated using least square means (LS means) of weekly salad deterioration evaluation.

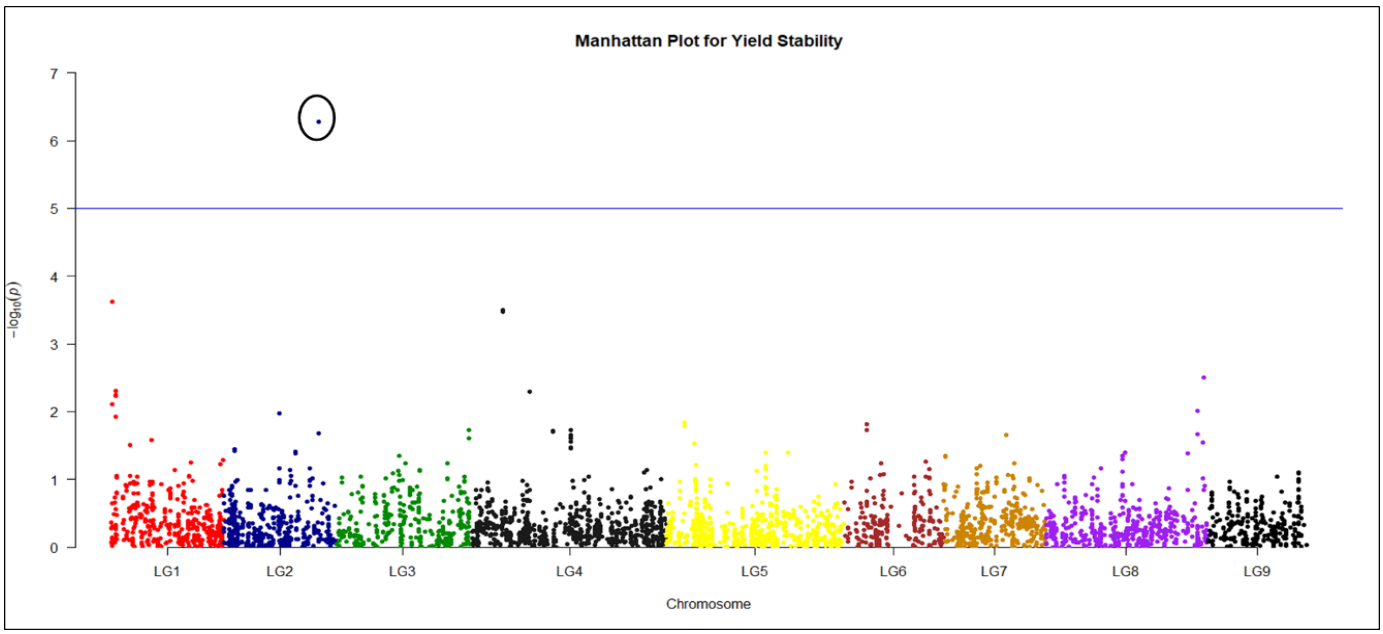


Figure 3. Genome-wide association study for yield stability of lettuce accessions showed significant marker-trait association on chromosome two. The above Manhattan plot was created using Wricke's ecovalance (a type of dynamic stability measure) calculated for each accession using yields from three field experiments in 2017.

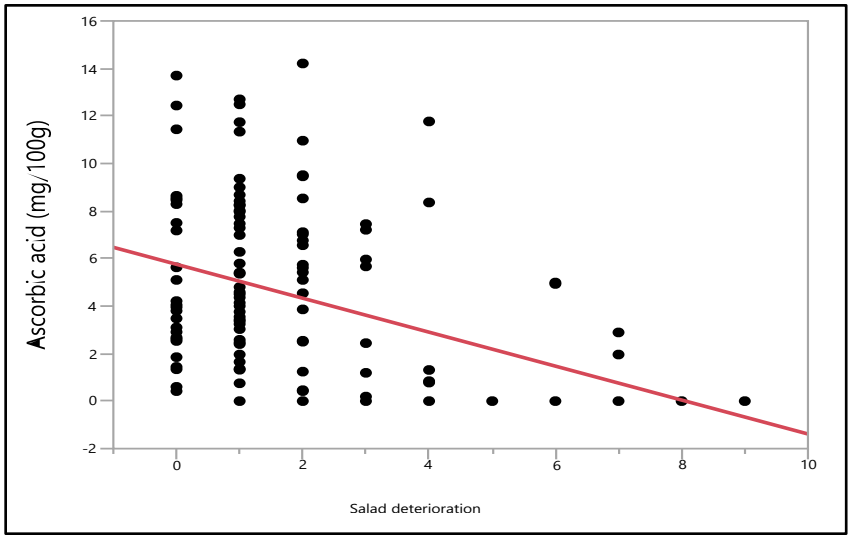


Figure 4. Regression analysis of ascorbic acid (vitamin C) on salad deterioration of 50 lettuce accessions showing that amount of ascorbic acid decreases as salad deterioration increases. Ascorbic acid was measured on packaged salad stored at

4°C for two weeks. Before ascorbic acid extraction, salad bags were visually evaluated for deterioration using the scale of 0 through 10, where the rating corresponds to $1/10^{th}$ of the estimated percentage of deteriorated tissue. Ascorbic acid (mg/100g) = 5.7572922 - 0.7141078*Salad deterioration. R^2 = 0.182

The project identified lettuce accessions with good shelf life, high yield, shelf-life stability, and yield stability from about 500 lettuce accessions. It determined the quantitative trait loci (QTL) for good shelf life in chromosome four. Major quantitative trait loci for deterioration of fresh-cut lettuce were reported previously in chromosome four in a recombinant inbred line population of Salinas 88 x La Brillante. The project has confirmed position of the QTL which will help in fine mapping of the gene associated with slow rate of deterioration. Molecular markers closely linked with the QTL can be applied for marker-assisted breeding for good shelf life. GWAS also determined QTL for yield, yield stability, and shelf-life stability. The project also identified accessions with high amounts of nutrients and good nutrient retention among 50 accessions.

Below is a table of the list of 50 lettuce accessions with their lettuce type and nutrient contents evaluated during the first week of salad processing. Data from the 2017 late-season experiment has been presented here.

Table 1: List of 50 lettuce accessions with lettuce type and nutrient contents (ascorbic acid, beta carotene, sugars) during the first week of salad processing.

SN	Accession	Lettuce Type	Ascorbic acid (Vitamin C) (mg/100 g)	Total beta carotene (mcg/100 g)	Total sugars (%)
1	UC96US23	L. serriola	18 A	153 A	0.6 F
2	Balady Barrage	Romaine	16.6 AB	71.9 ABC	1.7 ABCDE
3	Taiwan	Romaine	15.1 ABC	109.2 ABC	0.8 EF
4	Caesar	Romaine	14.7 ABC	59.8 ABC	2.2 AB
5	PI 358033-1 -COS- Bela Marula	Romaine	14.7 ABC	64.8 ABC	1.5 ABCDE
6	Inverno de Mall	Romaine	14.7 ABC	53.8 ABC	1.8 ABCDE
7	Gardenia	Romaine	13.8 ABC	56.1 ABC	1.9 ABCD
8	PI 257288	Romaine	13.4 ABC	54.7 ABC	1.7 ABCDEF
9	PI 491086	Romaine	12.9 ABC	119.5 AB	1.1 CDEF
10	PI 278074	Romaine	12.9 ABC	61.5 ABC	1.7 ABCDE
11	SM13-R3	Romaine	12.7 ABC	44.9 BC	2 AB
12	Green Towers	Romaine	12.2 ABC	84.8 ABC	1.8 ABCD
13	Romance	Romaine	11.9 ABC	69.1 ABC	2 AB
14	Valmaine	Romaine	11.9 ABC	79.3 ABC	1.8 ABCD
15	Bandit	Romaine	11.7 ABC	64.6 ABC	1.7 ABCDE
16	Green Forest	Romaine	11.6 ABC	59.5 BC	2 AB
17	Darkland	Romaine	11.3 ABC	73.1 ABC	1.6 ABCDE
18	Romaserra	Romaine	11.1 ABC	43.9 BC	1.5 ABCDE
19	Romanor	Romaine	10.7 ABC	40.2 BC	1.5 ABCDE
20	Triple Threat	Romaine	10.6 ABC	33.6 BC	2.2 A
21	SM09A	Romaine	10.6 ABC	76.3 ABC	1.6 ABCDE

SN	Accession	Lettuce Type	Ascorbic acid (Vitamin C) (mg/100 g)	Total beta carotene (mcg/100 g)	Total sugars (%)
22	Eruption	Romaine	10.2 ABC	49.2 BC	1 DEF
23	Alpi	Romaine	10.1 ABC	52.6 BC	1.7 ABCDE
24	Siskiyou	Romaine	10 ABC	59 ABC	1.8 ABCDE
25	PI 491038	Romaine	10 ABC	79.8 ABC	1.5 ABCDE
26	SalVal-321	Romaine	9.8 ABC	58.8 BC	1.9 ABC
27	Floricos	Romaine	9.8 ABC	89.2 ABC	1.9 ABC
28	RH13-0024	Romaine	9.8 ABC	76.4 ABC	1.7 ABCDE
29	Solar	Romaine	9.8 ABC	64.5 ABC	1.6 ABCDE
30	Ultegra	Romaine	9.7 ABC	65 ABC	1.6 ABCDE
31	Conquistador	Romaine	9.4 ABC	77 ABC	1.9 ABCD
32	Balady Cairo	Romaine	9.2 ABC	52.1 BC	1.6 ABCDE
33	FLA. 24069	Romaine	8.9 ABC	59.7 BC	1.8 ABCD
34	Queen of Hearts	Romaine	8.9 ABC	80.8 ABC	2 AB
35	PI 278100 0-COS-38	Romaine	8.9 ABC	46.1 BC	1.7 ABCDE
36	Little Lepricon	Romaine	8.8 ABC	58.7 BC	1.3 BCDEF
37	Parris Island Cos	Romaine	8.7 ABC	58.2 BC	1.7 ABCDE
38	PI 665200	Romaine	8.5 ABC	38.4 BC	1.9 ABCD
39	HeavyHeart	Romaine	8.3 ABC	93.8 ABC	1.8 ABCD
40	Lee Tal	Romaine	8.1 ABC	66.5 ABC	1.5 ABCDE
41	Clemente	Romaine	7.9 ABC	39.5 BC	2 AB
42	SM09B	Romaine	7.9 ABC	55.1 BC	1.8 ABCD
43	La Brillante	Batavia	7.7 ABC	72.4 ABC	0.9 EF
44	Little Gem	Latin	7.6 ABC	66.8 ABC	1.3 BCDEF
45	SM13-R2	Romaine	7.6 ABC	39.1 BC	1.6 ABCDE
46	Rubicon	Romaine	7.3 BC	53.2 BC	2.1 AB
47	Salinas	Iceberg	7.3 BC	11.3 C	1.8 ABCD
48	Barcarole	Romaine	6.3 ABC	62.2 ABC	1.5 ABCDEF
49	Dark Green Romaine	Romaine	5.4 BC	35.9 BC	1.4 ABCDEF
50	Salinas 88	Iceberg	4.5 C	12.1 C	1.9 ABCD

[x]Means with different letters are significantly different (Tukey's HSD, $p < 0.05$)

Among the 50 tested accessions, *Lactuca serriola* (a wild lettuce) had significantly high vitamin C and beta carotene than any other accessions and significantly low sugar content. Iceberg types had lower vitamin C and beta carotene content and higher sugar. Romaine types were in the middle, however, there were wide variations among the cultivars. Figure 5 shows the graphical representation of the nutrient contents during the first week of salad processing. Accessions with higher nutrient contents can be cultivated for nutrient-rich salad and can also be used in breeding programs as well.

When the accessions were evaluated for change in nutrient contents with tissue deterioration, it was observed that in general, nutrient levels decreased with the increase in salad deterioration. Among beta carotene and sugar, sugar was observed to decay faster with tissue deterioration than beta carotene decay. Figure 6 and Figure 7 shows the regression analysis of beta carotene and sugar decay with salad tissue deterioration.

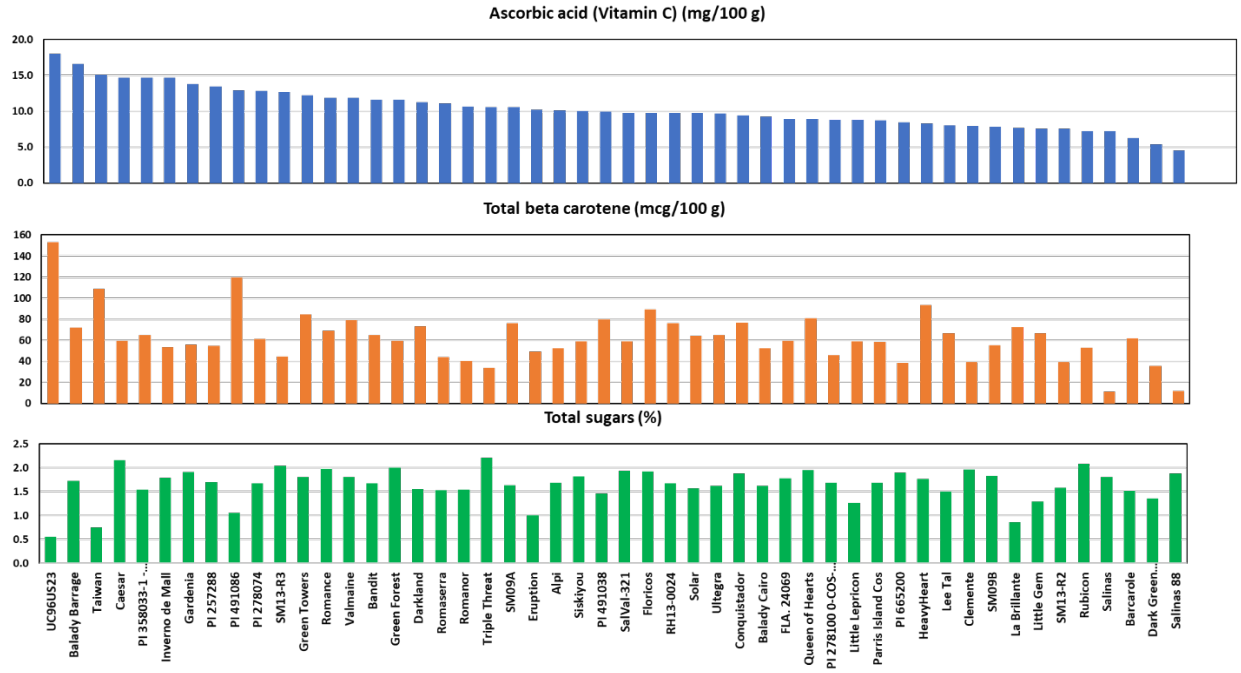


Figure 5. Graph of 50 lettuce accessions with their nutrient contents (ascorbic acid, beta carotene, sugars) during the first week of salad processing.

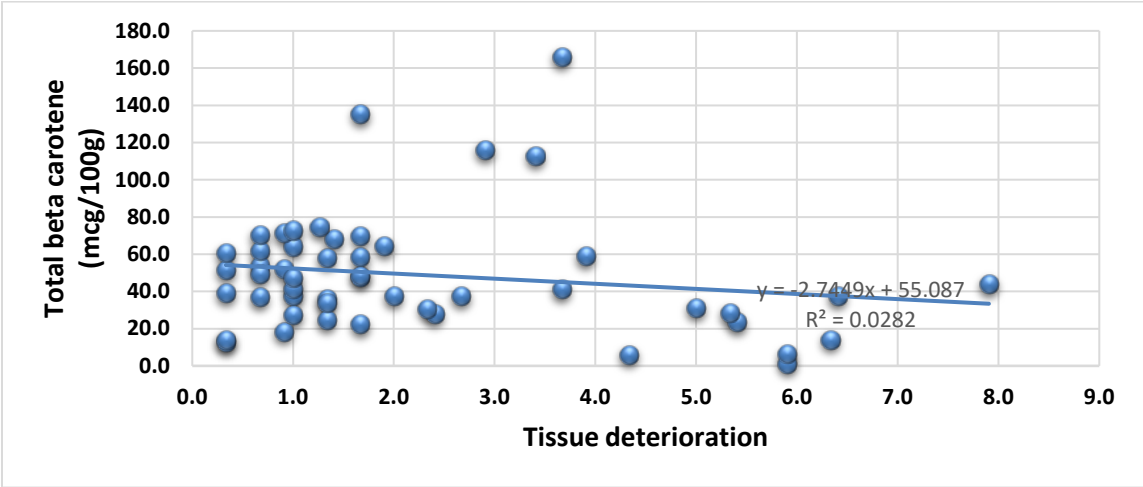


Figure 6. Regression analysis of total beta carotene (Vitamin A) on salad deterioration of 50 lettuce accessions showing that amount of beta carotene decreases as salad deterioration increases. Beta carotene was measured on packaged salad stored at 4°C for two weeks. Tissue deterioration is the LS mean

calculated from visual evaluation of salad bags from the same experiment using the scale of 0 through 10, where the rating corresponds to 1/10th of the estimated percentage of deteriorated tissue.

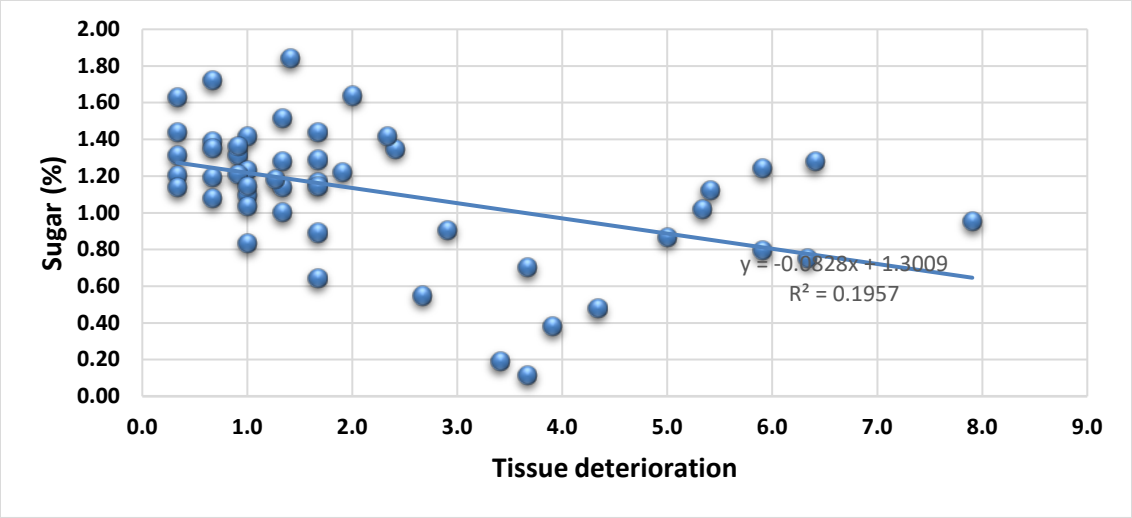


Figure 7. Regression analysis of Sugar content on salad deterioration of 50 lettuce accessions showing that amount of sugar decreases as salad deterioration increases. Sugar content was measured on packaged salad stored at 4°C for two weeks. Tissue deterioration is the LS mean calculated from visual evaluation of salad bags from the same experiment using the scale of 0 through 10, where the rating corresponds to 1/10th of the estimated percentage of deteriorated tissue.

Beneficiaries

Using nutrient-rich lettuce cultivars with extended shelf life and better yield in lettuce production and for breeding purposes will significantly benefit the lettuce industry of California including growers, packers, shippers, seed companies, and researchers, as well as consumers. Lettuce production in California in 2017 was worth over 2.4 billion dollars according to the Vegetables 2017 Summary of USDA-National Agricultural Statistics Service. California is the primary producer of fresh market lettuce and will be the primary beneficiary from improved lettuce cultivars.

Lettuce with improved nutrition, good nutrition retention, and extended shelf life is more desirable to consumers and will decrease salad waste and the frequency that lettuce is replaced in the market. This will certainly conserve production resources. Lettuce with better yield and yield stability will directly benefit economies of lettuce growers and companies. There are 12 breeding companies, over 10 packing companies, over 120 growers that supply lettuce in the Salinas and Pajaro Valleys, which means that over 199,700 acres in California, and consumers could benefit from this research.

Lessons Learned

The goals of the project were mostly achieved, however, in one instance, exact outcome measures were not fulfilled. Regarding identification of cultivars that remain saleable for more than 20 days, four field experiments were performed. Among the four, all the experiments had accessions that remained fresh with no decay until three weeks, still accessions that had equal performance in all were hard to find. There are many factors that can affect the performance and nutrient contents of the accessions. Environmental factors of the field location and time of the year had influence, in addition, storage conditions of the harvested plants and

time of salad processing had effect. Shelf-life stability analysis determined accessions with most stable shelf life among all the experiments.

Additional Information

Below are the presentation abstracts that were presented at the scientific conferences:

- Sthapit Kandel, J., Mou, B., Hayes, R. J., and Simko, I. 2018. Genome-wide association study of deterioration in fresh-cut lettuce. 2018 American Society of Plant Biologists, Annual Meeting, Montreal, Canada.

- Sthapit Kandel, J., Mou, B., Hayes, R. J., and Simko, I. 2017. Genome-wide association study for lettuce cultivars with improved salad processing efficiency. 2017 ASHS Annual Conference. HortScience 52(9):S369.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
16	Linking Farms to Schools for Nutrition-Based Learning	
Grant Recipient: School Garden Network of Sonoma County	**Grant Agreement No.:** SCB15016	**Date Submitted:** December 2018
Recipient Contact: Sue Davis	**Telephone:** (415) 812-3924	**Email:** sue.davis@schoolgardens.org

Project Summary

Diet-related chronic disease and obesity continue to be at epidemic levels in the United States. Children are increasingly disconnected from their food sources and how food is produced, preferring packaged food to fresh produce. As the places where children spend much of their time and often eat at least half their calories, schools are a primary driver in young people's experiences with food; therefore, schools have the opportunity to be a critical point of intervention in the health of students.

This project addressed gaps in nutrition and specialty crop consumption in Sonoma County with a robust, county-wide farm-to-school program including 1) Harvest of the Month (HOTM) fruit and vegetable tastings; 2) Farm field trips; 3) School garden technical and financial assistance; 4) Garden & nutrition classes; and 5) Specialty crop cooking and nutrition education workshops. This project was designed to increase specialty crop consumption in adults and children as well as generate revenue sources for California farmers. The education model of this project increased awareness of how to purchase and prepare specialty crops for adult consumers and encourage youth to become informed eaters through exposure to new and familiar specialty crops.

Introducing students to both new and familiar specialty crops at a young age ultimately results in less food wasted in cafeterias and creates life-long healthy habits that prevail off campus as students develop preferences for fresh food. School garden and nutrition programs have been shown to improve students' recognition of, attitudes towards, preference for, and willingness to taste specialty crops. In addition, field trips to local farms help students understand and connect with where their food comes from and ultimately build relationships between farmers, schools, student and their families. Schools can provide farmers with a viable market through increased purchasing of specialty crops while farms supply schools with the freshest food possible. These school programs are powerful learning tools, exposing students to the true nature of food and how they can participate in the food system. However, they require funding and experienced guidance for success, which is often a barrier for many schools. This grant award helped lift this barrier and provided the opportunity for a select number of Sonoma County public schools to create the foundation for a long-term and comprehensive farm-to-school program. The overall objective of this project was to increase knowledge of, access to, and consumption of California specialty crops by creating new markets and revenue streams for local specialty crop growers, increasing student awareness and consumption of specialty crops though the HOTM program, school garden programs, garden nutrition classes, and increasing community awareness of and access to local specialty crops and growers.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

This multifaceted project addressed the priorities of strengthening school garden programs, providing classroom and garden education, linking schools and farms, and providing food access and cooking workshops for adults. The partnership between FoodCorps, Community Alliance of Family Farmers (CAFF) and School Garden Network (SGN) was successful in accomplishing its impact and measurable outcomes. Together FoodCorps & CAFF created new markets and steady revenue streams for local specialty crop growers by targeting Sonoma County schools. The first objective established from this project- create new markets and steady revenue streams for local specialty crop growers- was executed successfully.

Throughout the grant period, relationships were built with three school district's food service programs- Wright School District, Healdsburg Unified School District, and Windsor Unified School District – and efforts were made to connect them with local growers to navigate local purchasing efforts. CAFF facilitated monthly purchases from farmers highlighted in the HOTM Program. Specialty crops were used as tastings in the cafeteria during the same or following week the HOTM in-class tastings were happening. Wright Charter School spent $299.50 on local and California specialty crops. Healdsburg Unified School District made more local specialty crop purchases in the 2017-18 school year. A relationship was formed with Middleton Farm in Healdsburg and local purchasing began in September 2017. Windsor Unified School District connected with their current distributors and requested that all specialty crops sourced within 250 miles of the school be reported on their invoices and they agreed to comply. By the end of the 2016-17 school year, Windsor Unified spent $5,905 on local specialty crops.

The SGN Project Manager (PM) provided ongoing technical assistance and mentoring to grantee school gardens and coordinators. First, the PM selected the grantee schools and wrote contracts with each school, including language requiring schools to use funds for specialty crops only. PM routinely worked with grantee schools and offered assistance with a variety of different topics ranging from how to secure ongoing funding for their program, when to plant specialty crops and what to plant, how to design an outdoor learning classroom, and creating lesson plans that revolve around specialty crops and Next Generation Science Standard (NGSS) science standards. Year 1 mentorship focused on forming individual relationships with each coordinator to help them with specific projects such as planting guides for their school, providing program development for schools that did not have an already existing program and supporting staff. Year 2 mentorship focused both on forming individual relationships as well as facilitating the formation of a learning cohort.

SGN's financial and technical assistance focused on providing stability to garden programs and expertise in garden design and curriculum highlighting California specialty crops. During the grant cycle, SGN distributed $45,000 of direct funding to nine school garden programs.

PM facilitated five workshops for grantee schools and topics included garden prop making; curriculum resource development and sharing; irrigation design and installation; garden sign making; curriculum development and preparation for the following year. The workshop locations alternated between grantee school sites so that all coordinators could have the opportunity to share their gardens with the group. A shared Google Drive folder was used to allow all schools to share curriculum, activities, and other pertinent information with each other. Over the course of this grant, facilitating opportunities for garden educators to interact and become familiar with each other over time encouraged them to reach out to each other for guidance, support, and inspiration. As a result of this mentoring, schools have indicated increasing the production of specialty crops up to 40 percent within their school garden.

The PM also coordinated farm field trips for grantee schools to farms that focus on growing specialty crops. Over the grant, more than 300 students attended field trips at nine local farms. For all field trips, this grant provided financial compensation for school's transportation costs, as well as a financial stipend per farm visited. On these farm field trips, children and parent volunteers were welcomed to explore a farm located within a few miles of their child's school. Classes were divided into smaller groups so all children could rotate through participative activities. Each farm offered a chance to harvest and eat something and many farms offered opportunities where children could engage in a project. Teachers were very happy about being able to offer their children this field trip and reported that without the help of the grant, it would have been very difficult to arrange and fund this type of excursion.

The CAFF HOTM tasting kits program allowed students access to locally produced specialty crops and educated them around the importance of these crops for nutrition and the future of farming in the region. Each month, the FoodCorps Service Member and the Farm to School Coordinator (FSC) procured specialty crops, created educational materials, assembled the tasting kits, and coordinated the delivery of the kits to schools throughout Sonoma County. HOTM program focused on one locally grown specialty crop each month. All activities provided to schools revolve around this produce item and the specialty crop farmer who grew it. Student participation in HOTM was measured showing an increase in student's wiliness to try new foods through the regular tastings in the cafeteria and classroom. By the end of the 2017 school year, this HOTM program reached over 8,880 students.

Healthy Roots Nutrition Education Program (NE) provided on-site nutrition education and cooking in the garden classes to grantee schools, allowing the students to link specialty crop production with healthy eating. During the grant cycle, 62 nutrition education and cooking lessons were conducted serving approximately 500 students, approximately three times per year.

Onsite nutrition education and cooking class time was split into three segments: nutrition lessons, recipe/activity, and tasting/conclusion. Nutrition lessons covered topics ranging from nutrition as a science, to understanding how to read a nutrition label, understanding terms such as "crop," "local," "in-season," and "nutrient dense," to using senses (sight, touch, smell, taste) to help choose fresh produce and discover new taste experiences, and much more. Activities included: Coloring pages featuring specialty crops and making a rainbow of crops display; Nutrition Label creation; Crop Scavenger hunt; Specialty crop taste testing and recognition using five local and in season crops. For the cooking and activity segment, students were split into groups. Part of the class worked on food prep while the remaining students worked on an activity relating to the oral lesson conducted in the beginning of class. Students followed written and oral directions for recipes and performed all tasks. Lastly, the tasting/conclusion activities included students presenting foods to their fellow peers. Student were encouraged to taste everything, chew quietly and thoroughly before making any comments or remarks about the food. This end of class discussion was always enjoyable and fruitful.

The NE also conducted Food Access and Nutrition Workshops (FANW). These workshops are bilingual and designed to inform participants of the benefits of sourcing and eating locally grown specialty crops, how to buy specialty crops directly from farmers, how to use food stamps at farmer's markets, and to provide a hands-on cooking experience using specialty crops. All recipes and resources, including a list of local farmer's markets were given out in English and Spanish. FANW helped to create new habits in food purchasing and encouraged simple home-prepared foods that use specialty crops and that families can enjoy together. In Year 1, two FANW workshops were completed yet only about 33 adults attended. Year 2;

however, two FANW workshops were conducted and approximately 20 adults attended each session. In total, the FANW impacted approximately 77 adults, with the most significant measurable outcome being a 49.5 percent increase in people purchasing specialty crops from farmers markets in the post survey.

This project solely enhanced the competitiveness of specialty crops.

While the SGN held the reins of this robust Sonoma County-wide farm to school project, the contributions of FoodCorps and CAFF as project partners was critical to the scope and success of the accomplishments.

The FoodCorps and CAFF were tasked with the goal of creating new markets and revenue streams for a minimum of three local specialty crop growers. They worked with school food service directors to source more local specialty crops and promote it to students. Through their roles, they collected benchmark data for sales and were able to successfully initiate a commitment from three food service directors to purchase more local specialty crops for the school's meal program, while simultaneously incorporating activities and educational materials in their cafeteria, such as a farmer profile highlighting the specialty crop farmer who grew the produce, and cafeteria promotions encouraging consumption of the HOTM produce and farm visits.

In addition, CAFF also contributed to an increase in student knowledge and nutritional awareness of specialty crops by outreaching to all school districts in Sonoma County promoting HOTM and providing ongoing technical assistance to teachers through HOTM tasting kit trainings, fundraising resources and in class assistance when requested.

Goals and Outcomes Achieved

Outcome 1: Create new markets and revenue streams for a minimum of three local specialty crop growers.

- Activity: FSC/CAFF & FoodCrops conducted outreach with schools, farms and local distribution networks to establish baseline data & eventually to make connections for specialty crop growers and local schools that want to purchase local specialty crops.
- Activity: FoodCorps worked closely with food service staff to aid them in improving the cafeteria by researching signage options, assisting in regular cafeteria tastings, and providing connections to farmers for local purchasing.

Outcome 2: An increase in student knowledge and nutritional awareness of specialty crops amongst at least 50 percent of the students who received the HOTM program, participate in garden and nutrition classes, or go on farm fieldtrips.

- Activity: PM, NE, FSC conducted pre-test surveys to determine baseline date via pre-test surveys on student's access or, preference for and assessment of specialty crops.
- Activity: PM conducted outreach to local farms to determine appropriate hosts for school field trips, worked with each school to select two classes to participate in farm field trips, talked with farm staff and teachers to develop a schedule and activities, and accompanied class on field trip and often led a group at the farm to enable the class to be divided into smaller groups.
- Activity: FoodCorps Service Member and Farm to School Coordinator provided ongoing technical assistance to school requests, such as with in-class HOTM lessons and monthly promotional activities connecting the cafeteria to the HOTM educational content.

- Activity: NE provided onsite nutrition education and cooking classes allowing the students to link specialty crop production with healthy eating. The NE visited between 2-4 classrooms, three times per year, in each of the 10 grantee schools.
- Activity: PM, NE, FSC conducted post-test surveys to determine a change in knowledge of and preference for specialty crops using questions identical to pre-test surveys.

Outcome 3: Increase the number of Sonoma County school campuses that grow specialty crops for educational purposes by 10 percent over two years.

- Activity: PD/PM administered online surveys to school garden coordinators about specialty crops growing in school gardens to establish a benchmark for monitoring progress from promoting specialty crops.
- Activity: PM provided ongoing technical assistance and mentoring to nine grantee school gardens and coordinators, focused on providing stability to garden programs and expertise in garden design and curriculum highlighting California specialty crops. PM also facilitated five workshops for grantee schools and topics included garden prop making; curriculum resource development and sharing; irrigation design and installation; garden sign making; curriculum development and preparation for the following year.
- Activity: PM/PD evaluated data collected about specialty crops grown in school gardens to provide details on progress made in promoting specialty crops

Outcome 4: An increase in adult knowledge of specialty crops, local growers and how to cook with specialty crops amongst at least 50 percent of the adults that participate in the food access and nutrition workshops.

- Activity: NE administered pre-workshop surveys to evaluate knowledge of and access to local specialty crops
- Activity: NE facilitated four FANW to families of school communities. These workshops are bilingual and designed to inform participants of the benefits of sourcing and eating locally grown specialty crops, how to buy specialty crops directly from farmers, how to use food stamps at farmer's markets, and to provide a hands-on cooking experience using specialty crops.
- Activity: NE administered post-workshop surveys to evaluate changes in participant's knowledge of and preference for specialty crops

Activity/Goal	Actual Accomplishment	Comments
Facilitate relationships between food purchasers in 1-2 school districts and local specialty growers	SGN was able to facilitate relationships with three school districts	Healdsburg Unified School District; Windsor Unified School District; Wright School District
Establish baseline data on annual dollars spent by food service departments on specialty crops from local growers	CAFF & FoodCorps worked with school food service and their produce distributors to gain information about what produce is 'local,' and to assist these distributors in implementing tracking procedures and mechanisms to follow the product from farm to end customer	Many produce distributors do not track products closely enough to prove that the product is in-fact from the local farm it claims to be. Schools preferred to work with a local farm directly or to stay with their existing distributor.

Activity/Goal	Actual Accomplishment	Comments
Monitor and evaluate increases in dollars spent by food services departments on specialty crops from local growers	CAFF and FoodCrops worked closely with school food service directors, produce distributors and local farmers to track specialty crops and to encourage transparency in the purchasing chain. Also, CAFF promoted schools work directly with farmers, and or distributors that are willing to track goods.	Again, without tracking procedures and mechanisms in place by produce distributors, it's difficult to say for certain what is 'local.'
Conduct outreach to all school districts in Sonoma County to have 200 classrooms participate in HOTM from 2015-16 & 2016-17 (recruit/enroll schools)	In September 2015, 123 classrooms participated in the program. By the end of the school year, participating classrooms increased to 223. By the end of the 2016-17 school year 296 classrooms participated in the program. The overall number of kits delivered increased 73 percent by the end of the grant period.	Robust outreach efforts were the main factor in increasing program participation.
Design evaluation tools and implementation plan for HOTM and for school garden and nutrition classes at grantee schools	All evaluation tools and surveys were created and implementation of plan was executed.	
Administer pre-test surveys to students participating in HOTM and to students in the garden and nutrition classes at grantee schools	Pre-experience surveys were administered to students and these results were entered into a google form	
Implement HOTM: procure produce, create educational materials, assemble tasting kits monthly, and coordinate delivery of the tasting kits to schools	Fifteen teacher trainings were provided to new schools, which included technical assistance for using HOTM, lesson ideas and recipe suggestions. By the end of the 2017 school year, HOTM reached over 8,880 students.	
Provide three garden nutrition education classes per year to each grantee school	NE visited multiple classes at each grantee school three times per year	
Design farm field trips and evaluation tools	Farm field trip program developed. Pre and post survey developed	Survey changed from Year 1 to Year 2 based on feedback from teachers as well as insight gained

Activity/Goal	Actual Accomplishment	Comments
		from analyzing survey results in Year 1
Conduct outreach to schools to participate in farm field trips	Accomplished.	
Administer pre-test surveys to students that participate in farm field trips	Accomplished. In Year 2, teachers administered the pre-test surveys	Some teachers forgot to administer the pre-test surveys prior to attending the field trips. Even so, PM collected more than required number of surveys
Coordinate farm field trips with schools and farmers	Eleven field trips in Year 1, and nine field trips in Year 2. A total of 20 field trips	PM successfully formed relationships with local farms that grow specialty crops
Administer post-test surveys to students that participate in farm field trips	PM visited classroom after farm field trip and administered post-test surveys	
Design survey and evaluation tools for four food access and nutrition workshops	NE & PD worked together in Aug/Sept 2016 to develop survey and tools	
Administer four food access and nutrition workshops	NE offered two in year 1 & 2 in year 2.	FANW impacted 77 adults, with a 49.5 percent increase in people purchasing specialty crops from farmers markets in the post survey
Increase the number of Sonoma County schools that grow specialty crops in their school gardens for educational purposes by at least 10 percent	PM was able to collect pre and post data on schools in which SGN awarded the $5,000 mini-grant, and saw an increase of 47 percent in schools that produce specialty crops for educational purposes	It was outside the scope of staff abilities to collect data on schools that were not directly assisted through the mini-grant provided
An increase in student knowledge and nutritional awareness of specialty crops amongst at least 50 percent of students who…go on a farm field trip	PM administered pre-post test surveys to more than the required number of students but did not see 50 percent increases in knowledge of specialty crops	The sample of students surveyed primarily had prior knowledge of specialty crops. These students have also been participating in their school's existing garden program. This could explain why so many students had high baseline knowledge of specialty crops

This project strived to achieve four clearly defined outcomes:

Outcome 1: Create new markets and revenue streams for at least three local specialty crop growers.

With the collaboration and effort of CAFF, SGN and FoodCorps, information about school food service purchasing of specialty crops was gathered and analyzed. Schools were very receptive to receiving support in enhancing their usage of local and specialty crops. CAFF facilitated relationships with three school's food service directors to connect schools with local farms and a local produce distribution company, FEED Sonoma, that tracks all its products from farm to customer. For sourcing HOTM produce, staff worked with 19 farms- nine farms in year 1 and 10 farms in year 2- each featuring one specialty crop grown by that farmer.

Outcome 2: An increase in student knowledge and nutritional awareness of specialty crops amongst at least 50 percent of the students who received the HOTM program, participate in garden and nutrition classes, or go on farm fieldtrips.
The goal of increasing student knowledge and nutritional awareness of specialty crops was achieved and the data shows a transformation in students from passive consumers to specialty crop eaters and advocates who make informed choices and interact with their food producers. After participating in the HOTM program for nine months in the 2016/17 school year, over 700 surveys were analyzed and 94 percent of students said they like to try the HOTM fruit or vegetable, 87 percent know that eating fruits and vegetables every day can give them more energy to play, 86 percent more students asked a parent to buy their favorite fruit or vegetable, and 78 percent of the students know that their favorite fruit grows on a plant before they get to eat it. By the end of the 2016-17 school year 296 classrooms participated in the HOTM program. The overall number of kits delivered increased 73 percent by the end of the grant period. For the Healthy Roots NE students showed an increase in all areas surveyed. By the end of the NE program, 74 percent of students said they like to eat fruits and vegetables, 59 percent said they like to try new fruits and vegetables, and 94 percent of students ask parents to buy fruits and vegetables at home. More than 300 students from 10 schools attended fieldtrips to a local farm. 20 fieldtrips in total were coordinated to 9 local farms. For farm field trips, survey results demonstrated that after students visited a farm, they were more aware that strawberries, apples, and plums grow in California. From field trips, students also reported both an increased preference for fruits and vegetables and an increased willingness to try fruits and vegetables. Students had greater awareness that fruits and vegetables help them grow and are a necessary component of a balanced diet.

Outcome 3: Increase the number of Sonoma County schools that grow specialty crops in their school gardens for educational purposes by at least 10 percent.
Of the 19 Sonoma County Schools participating in the HOTM program, zero schools were growing specialty crops in their school gardens for educational purposes. Nine schools were given sub-grants to help strengthen the design and capacity of the school gardens, with a focus on the production of specialty crops for educational purposes. This is a 47 percent increase.

Outcome 4: An increase in adult knowledge of specialty crops, local growers and how to cook with specialty crops amongst at least 50 percent of the adults that participate in the food access and nutrition workshops.
In total, 32 adult participants of FANW were surveyed. Results showed that more adults reported interest in purchasing specialty crops from sources other than the grocery store such as farmer's markets, direct farm purchases or growing their own gardens. Results showed a positive impact of FANW on where families purchase their specialty crops: a 49.5 percent increase in purchasing specialty crops from the farmer's market; a 200 percent increase in purchasing specialty crops from a farm stand; a 100 percent increase in considering growing their own specialty crops at home; and a 37.5 percent decrease in purchasing specialty crops from chain grocery stores post workshops. In addition, there was a 50 percent increase in families that report wanting to cook more meals at home after attending FANW. Furthermore, the pre-surveys showed that 77

percent of attendees used at least five specialty crops in each meal before attending the workshops, and post workshop survey results showed a 15 percent increase in attendee's desire to use more specialty crops in each meal. In conclusion, the FANW were a success. Workshop discussions were focused on nutritional aspects of fresh foods and facilitating an opportunity for children and parents to use specialty crops to prepare meals together and families were excited about local specialty crops and supporting local farmers.

Highlights of the project:

- Facilitated local specialty purchasing with three school food service programs
- Purchased HOTM specialty crop from 19 local farms and highlighted the farmer and product
- Created a selection committee and facilitated a competitive grant process for selecting schools to receive the program's multi-faceted components
- During the grant cycle, SGN distributed $45,000 as direct funding to nine school garden programs
- More than 300 students attended field trips at nine local farms.
- By the end of the 2017 school year, the HOTM program reached over 8,880 students.
- Sixty-two nutrition education and cooking lessons were conducted by NE serving approximately 500 students.
- FANW impacted 77 adults, with the most significant measurable outcome being a 49.5 percent increase in people purchasing specialty crops from farmers markets in the post survey.

Beneficiaries

- Teachers: Teachers benefited in many ways. Teachers that attended farm field trips learned which farms are interested in hosting school groups and how to facilitate a farm fieldtrip for the future. Teachers also benefited from the HOTM 'teacher trainings,' and their related tasting kits and educational materials.
- Students: Students benefited from attending farm field trips, receiving HOTM produce in their classroom, eating specialty crops in their school meals, and participating in cooking from the garden lessons and activities. Students learned about food systems and why eating locally grown and in season crops has health benefits extending beyond the body and into the environment.
- Garden Coordinators: Garden coordinators benefited from the direct mentoring and technical support by the PM, program funding, and the group workshop series. Garden coordinators also benefited from working alongside the NE to create delicious and nutritious recipes and information of specialty crops.
- School Administrators: School administrators benefited from the additional publicity their schools received from SGN, as well as receiving support for their garden program and getting guidance on how to continually integrate the garden program into the culture of the school community.
- Parents (including Volunteers): Parent volunteers who attended farm field trips were exposed to farms located close to where they live that welcome family participation. Also, parents who participated in the FANW received food access and nutrition information about eating and sourcing locally grown specialty crops, as well as the recipes prepared in the workshop.
- Local Farms: Local farms and farmers benefited from an increase in awareness about their farm, educating communities about specialty crops and the importance of eating locally and seasonally.
- School Food Service Directors: School Food Service Directors/workers benefited from the technical support and assistance of FoodCorp and CAFF to connect local producers or distributors to the school who can supply specialty crops.

Teachers: 329
Students: 9,680 (8,880 HOTM, 300 farm field trips, 500 NE cooking from the garden classes)
Garden Coordinators: 9
School Administrators: 15
Parents (Including volunteers): 137
Farms: 28
School Food Service: 3

Lessons Learned

Lessons Learned from Farm Field trips:

- Offer farm field trips and nutrition education classes to the same group of students to have continuity of information/concepts/language and thus a deeper impact on the potential positive impact this information has on students
- Offer same class two farm field trips (spring and fall) instead of taking 2 classes on one field trip each
- Modify farm field trip survey questions to reflect specialty crops grown in Sonoma County instead of focusing on the entire state of California
- Visit each classroom once to talk about farms, establish expectations, and set learning objectives

Lessons Learned from School Garden Mentoring & Technical Assistance

- Work more closely with school administrators from the very beginning to develop long term garden funding plans
- Digitize the surveys for more efficient data entry and analyses

Lessons Learned from working with food service to increase local specialty crops in the cafeteria

- Most produce distributors that work with school food service do not track their produce from farm to customer so it was difficult to know for certain that specialty crops that were called local were in fact local.

Lessons Learned from Healthy Roots Nutrition Educator program

- Crop tasting activity was a huge success in that it gave the students the opportunity to use scientific methods for tasting crops. What is the flavor and texture, what part of the plant are you eating? This activity was the last activity of the year and in hindsight using it at the beginning of the program would be better because it helped students be more objective and open when tasting foods.
- Classes were more efficient and complete when garden coordinators were present so requiring his/her presence would be mandatory moving forward
- Recommend scheduling classes close enough together to share resources would allow for bulk purchasing of recipe ingredients

Lessons Learned from FANC

- Make sure all survey participants complete every question of the survey so results are easier to compile accurately.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
17	Real Kids, Real Food Farm to School Program	
Grant Recipient: Sierra Harvest	**Grant Agreement No.:** SCB15017	**Date Submitted:** December 2018
Recipient Contact: Aimee Retzler	**Telephone:** (530) 265-2343	**Email:** aimee@sierraharvest.org

Project Summary

Childhood obesity, chronic diseases related to diet, and food insecurity are issues for many residents of rural Nevada County which could be alleviated by the consumption of more specialty crops. The mission of Sierra Harvest (SH) is to educate, inspire and connect Western Nevada County families to fresh, local, seasonal food. While SH's Farm to School (FTS) program had increased knowledge and consumption of specialty crops among children and families during its first grant, there was still a lack of access to specialty crops and inadequate education related to the nutritional importance of specialty crops in schools. Additionally, specialty crop farmers often lacked the resources to implement comprehensive marketing plans for their specialty crops resulting in less residents knowing about and consuming their products, and needed outside support to promote demand for local specialty crops.

SH's FTS program is important and timely to the specialty crop industry because of the market opportunity that exists now to increase sales by improving access to and delivering education about specialty crops to over 7,000 school children and their families, and by contracting with local school districts to purchase specialty crops for school meal programs. One in six children in Nevada County are food insecure and one in five are overweight. Prior to SH's work on school meals, less than 25 percent of the student population purchased school meals due to their processed nature and lack of tasty, fresh ingredients. The overall objective of this grant was to achieve reductions in childhood obesity and food insecurity by expanding access to and improving nutritional awareness of California specialty crops in schools, creating healthy habits to last a lifetime.

This project built upon the 2012 Specialty Crop Block Grant Program Project 25: *Real Kids, Real Food Farm to School Program*. This current project built upon the existing SH FTS program, expanding the reach to 22 K-8 schools and increasing the purchasing of specialty crops for school meals, including salad bars. Through this grant, SH has also been able to reach an additional 3,000 high school students with Harvest of the Month (HOTM) tastings.

Project Approach

- Program expanded from 18 to 22 K-8 schools. Contracts were renewed annually with all schools.
- Farm to School Liaisons were hired and trained for each school annually.
- Seventeen specialty crop farm partners were contracted and connected with partner schools during the grant, and many of these relationships between schools and farmers have flourished.
- Ten regional farm potlucks were conducted each year to support the promotion of beginning and disadvantaged specialty crop growers. These potlucks were well-attended and promoted disadvantaged specialty crop growers through announcements on the SH website, via member emails and Facebook.
- Specialty crop sales were conducted by FTS liaisons at school produce stands ("garden carts") at 18 of the 22 schools for an average of eight weeks annually during August, September and October. Specialty crop

farm partners were contracted to provide the produce. Earnings from sales were held and tracked by SH to ensure their use only for allowable FTS programming and supplies.

- HOTM provided 7,043 students the opportunity to sample fresh, local specialty crops and taste the difference between farm-fresh seasonal produce and produce that has been optimized for longer shelf life. Specialty crop produce in the amount of 25,791 pounds, as well as educational materials were delivered to all classrooms monthly during the school year through HOTM. HOTM specialty crop tastings were conducted and surveys collected to measure the change in student preferences for specialty crops.
- Specialty crop Tasting Week was coordinated at each participating K-8 school annually in October. Guest chefs developed recipes and provided specialty crop cooking demonstrations and nutrition education.
- Field trips during the grant period provided 115 classes the opportunity to visit and learn about specialty crop farming on local partner farms.
- Specialty crop farm partners visited 183 classrooms during the grant period to teach students about farming specialty crops.
- 2,376 specialty crop plant starts were seeded and tended at the Food Love Farm for distribution to schools for their spring plants sales in early May of each year.
- A FTS start-up manual was written and FTS Replication Trainings were conducted for regional leads in neighboring communities to share SH's FTS model and successes.
- The Procurement specialist facilitated specialty crop procurement contracts between specialty crop farmers and school food service directors and created specialty crop promotional signage on campus. The procurement specialist tracked amounts and sales of local and regional specialty crops to school food service directors.
- Specialty crop farm partner coupon books were designed, printed, and distributed through produce stands and event outreach tables.
- Students at participating schools were surveyed annually (in addition to the monthly HOTM short survey) to measure program outcomes.
- Data from surveys and program elements was collected and analyzed, and reports written.

The project did not enhance the competitiveness of non-specialty crops. All specialty crop partner farmers are specialty crop growers.

Over the last six years SH's FTS program has engaged a diverse group of specialty crop stakeholders and given them time to develop mutually beneficial relationships, working towards common goals of increased access to and nutrition education about specialty crops. Nevada County school administrators, teachers, and parents have given their time and expertise to support nutrition education opportunities for students and families. Nevada Joint Union High School District Food Service (NJUHSD Food Service) has been a key partner in implementing increased amounts of specialty crops in school lunch for four high schools and two elementary schools.

The University of California Cooperative Extension has donated in-kind services and financial assistance for school gardens and taste tests. The Nevada County Public Health Department provided guidance on shaping policy through SH FTS programming. Nevada County Agriculture Commissioner and specialty crop partner farms have been an influential link in connecting farmers to schools and families, allowing specialty crop growers access to an increased market for their products

Participating schools have engaged in the many activities of the FTS program and now pay a per student participation fee to support a portion of the cost of the program. Liaisons from each school have coordinated all the FTS activities at their schools: picking up and delivering HOTM produce and educational materials to teachers, collecting surveys, coordinating Tasting week, field trips and farmer visits, running the produce stand at their school, conducting outreach to parents, and some of them have coordinated school gardens and provided hands-on garden education.

Specialty crop farm partners have provided produce for HOTM, hosted field trips, visited schools to provide classroom lessons, provided specialty crops for school produce carts and some have donated garden starts to school plant sales and school gardens. Guest Chefs have provided cooking demos using specialty crops to four classes at each school annually, and developed healthy, easy, kid-friendly recipes that were shared with families in the Tasting Week recipe books SH printed each year.

Goals and Outcomes Achieved

1) Goal: Increase preference for specialty crops among students. Monthly HOTM specialty crop produce tastings were conducted at 284 K-8 classes and three high school cafeterias September-May. Surveys were conducted by teachers in each K-8 class each month, recording the number of students who say they like a given specialty crop before and after a HOTM tasting, and the total number of students. A total of 104,997 students were surveyed using this HOTM survey**.** Data was entered in Survey monkey and analyzed to show trends (See Table 2, below). Other program activities, from Tasting week and school produce carts to a junior Iron Chef competition using specialty crops also supported the goal of increasing preference for specialty crops among students.

2) Goal: Increase specialty crop local produce access through procurement by NJUHSD Food Services director. The Procurement Specialist met with the NJUHSD Food Services director weekly, collected availability and price data from local specialty crop farmers, facilitated the purchase of specialty crops by the NJUHSD Food Services director, and tracked local and regional California specialty crop purchases each month. See Table 3 below.

3) Goal: Increase in participating families buying local specialty crops. Many project activities supported this goal: HOTM and Tasting week demos increased knowledge of and preference for specialty crops. Students consistently liked a produce item better after tasting a fresh, local sample or creative specialty crop preparation from these program activities. HOTM newsletters were sent home to families and provided nutritional information, recipes and serving suggestions for specialty crop items. Field trips and farmer-led classroom lessons allowed students to get to know local specialty crop farmers and learn about how they grow food. School produce stands provided students and their families an opportunity to sample and buy local, seasonal specialty crops conveniently at their school. Students were surveyed annually about where their families purchased food, and the percent that buy local and buy directly from farmers was tracked (see Table 1, below).

4) Goal: Increase gross sales of specialty crop partner farms. During the grant period 25,791 pounds of specialty crop produce was purchased from local specialty crop farmers for HOTM. 13,680 lbs of specialty crop produce was purchased for school produce stands from local specialty crop farmers during the same period. Project activities such as a farmer biography and photo on the HOTM newsletter

increased specialty crop farmers' visibility and sales. Gross sales data was collected from five partner specialty crop farmers, see Table 4, below.

While the targets for Goals 1 and 3 were not achieved, results showed positive outcomes with relation to the goals. Results did show progress toward Goal 1 (Increase preference for specialty crops among students), with the percent of students who liked a specialty crop consistently higher after tasting than before, for all three years of the grant. There was a 46 percent increase in the percentage of students who liked specialty crop items after tasting them as part of HOTM (see Table 2, below).

There was variation in the percentages of students who liked an item depending on the item sampled: mandarins were more popular than watermelon radishes, as would be expected. Student preference data can be expected to fluctuate annually depending on the specialty crop items sampled, and the initial benchmark and target were probably unrealistically high (the target, 90 percent of students saying they liked a specialty crop after sampling is very ambitious).

A long-term goal of the FTS program is that students learn to like many kinds of local, seasonal specialty crops. Specialty crop items were chosen specifically to provide students the opportunity to sample a wide variety of local, seasonal specialty crops, and to develop a taste for them. It often takes multiple times of trying the item to develop a preference for radishes, turnips, cabbages, etc. (all of which the students sampled) and SH intentionally chose some items that would be newer to students' palates and potentially more challenging to like. This may have resulted in a lower percentage of students liking the HOTM item and been a factor in not achieving the target.

Progress was also made toward Goal 3, an increase in participating families buying local specialty crops. The survey results indicate that most students' families purchased local specialty crops (59 percent) and purchased directly from farmers (58 percent) during the grant period. Because students were reporting on their families' food buying habits, there was likely some annual variation and error from students not being completely informed about their parents' food purchasing habits, so the original benchmark and target may have been unrealistically high. However, many students seemed familiar with where they would buy local and specialty crop items. The surveys asked students to circle the places their family gets food, including multiple farmer-direct options like CSAs, farmers' markets and produce stands, which were frequently all circled. The average percent increase in the percentage of students who could name a farmer was 79 from 2015-2018, increasing the visibility of local specialty crop farmers.

Table 1: Project Goals and Measured Outcomes:

Goal	Performance Measure	Benchmark	Target:	Measured Result:
1. Increase preference for specialty crops among students	Number of students who say they like a given specialty crop before and after a HOTM tasting	80 percent of students surveyed say they like a given specialty crop	90 percent of students	Before tasting: 50 percent liked After tasting: 72 percent of students liked, see Table 2

Table 1: Project Goals and Measured Outcomes:				
Goal	**Performance Measure**	**Benchmark**	**Target:**	**Measured Result:**
2. Increase specialty crop local produce access through procurement by NJUHSD food services director.	Produce purchases: lbs. of specialty crop produce procured in a school year (mid-August early June) in any grant year	Baseline at the beginning of the grant was 0 percent	Increase local produce procurement to 5 percent of total	2016/17: 692 lbs, 5 percent farmer-direct procurement of local or regional specialty crops 2017/18: 1778 lbs., 6 percent farmer-direct, local/regional See Table 3
3. Increase in participating families buying local specialty crops.	The percent of students who say their families buy local produce, shop directly from specialty crop growers; the number of farm partner coupons redeemed.	65 percent of students surveyed say their families shop at these outlets; 0 percent redeem coupons	75 percent of students surveyed; 35 percent coupon redemption.	59 percent buy local; 58 percent buy directly from specialty crop growers; 0.04 percent coupon redemption
4. Increase gross sales of specialty crop partner farms.	increased sales driven by project activities.	Baseline gross sales data obtained from five partner farms and changes in gross sales	Average 5 to 10 percent increase in gross sales.	Average 10 percent increase in gross sales, see Table 4

Goal 1: Additional details of survey data for Harvest of the Month are shown here in Table 2:

Table 2. Harvest of the Month Survey data

Year	**Total respondents**	**Percent liked before**	**Percent liked after**	**Percent increase**
2015-16	29,849	47%	74%	58%
2016-17	39,329	51%	71%	40%
2017-18	35,819	50%	72%	43%
Totals grant period 2015-18	**104,997**	**50%**	**72%**	**46%**

Goal 2: Local/regional specialty crop procurement goals for NJUHSD were achieved in 2016-17 and exceeded in 2017-18. Procurement data is shown below in Table 3:

Table 3. NJUHSD Procurement of Local and Regional Produce				
Year:	Local + regional lbs:	Local/Regional/Direct purchased	Total produce purchased	Local/Regional/Direct Purchased %
Baseline before grant				0%
2016-17	692.4	$1,603.88	$31,985.21	5%
2017-18	1778	$2,392.00	$42,654.77	6%

Goal 3: Baseline data and measured results for participating families buying local specialty crops are shown above in Table 1. The target percent increase was not achieved, but this may have been due to variability or inconsistent information from informants (students reporting on their families' food buying habits). Student reporting on family food buying may not be a reliable measure of whether families bought more local specialty crops or not. The survey asked where families purchased their food and did not have a way of measuring the quantities of local produce bought by participating families. Given the increase in farm partner sales (see Table 4, below) and the increase in the percentage of students who could name a farmer (79 percent from 2015-2018), progress was achieved toward connecting participants with local specialty crop farmers and increasing local consumption of specialty crops.

Goal 4: The target increase in specialty crop farm partner gross sales was achieved and exceeded, shown in Table 1, above, and in more detail in Table 4, below.

One of the major successful outcomes of this project was that it consistently brought local specialty crops to students and families through the tastings, school food service and school garden carts, offering repeated opportunities for students to sample and develop a preference for specialty crops. During the grant period, 39,471 lbs. of specialty crops were distributed to students and families through HOTM tastings and school garden carts. HOTM newsletters were distributed 27 times during the grant period to participating students, providing nutrition information, recipes and serving suggestions for the specialty crops featured by HOTM.

Three hundred classes participated in guest chef specialty crop cooking demonstrations during the grant period, where students had the opportunity to learn creative and tasty ways to prepare specialty crops, as well as sampling them. Recipe books from all the guest chef visits were also printed and distributed, giving families kid-friendly recipes focused on specialty crops.

A major success of this project is that partner specialty crop farms achieved a 10 percent increase on average in gross sales in one year during the grant period. One farm achieved a 35 percent increase in gross sales. The combined increase in sales was $49,347 for five partner farms.

Table 4. Farm Partners Gross Sales	2016	2017	Percent Change
Partner Farm 1	$122,000	$165,000	35%
Partner Farm 2	$125,000	$130,000	4%
Partner Farm 3	$94,000	$79,347	-16%
Partner Farm 4	$124,000	$132,000	6%
Partner Farm 5	$36,500	$44,500	22%
Total gross sales:	$501,500	$550,847	
Increase in combined sales:		$49,347	
Average % increase:		10%	

Another major accomplishment of the project is that the number of salad bars in participating schools increased from zero to six during the grant period because of SH's work with schools to promote specialty crop produce access.

Beneficiaries

The farm partners that benefitted from the project were all small-scale local and regional specialty crop growers. The farms ranged from one-half acre to 60 acres, mostly in Nevada County, California (the location of the project), with several farms in nearby Auburn, Marysville, Newcastle, and Aromas.

The students that benefitted from the Real Kids, Real Food FTS program were from 22 K-8 schools in western Nevada County. Additionally, students at four high schools benefitted from HOTM tastings, Junior iron chef specialty crop competitions, and incorporation of local and regional specialty crops into school food service meals. Forty-eight percent of the K-8 population in western Nevada County qualifies for free or reduced lunch. The opportunity to eat and develop preference for fresh, local specialty crops at school is particularly impactful for this low-income demographic, many of whom would not otherwise have much access to fresh specialty crops. One in six children in Nevada County are food insecure and one in five are overweight, and these students especially benefitted from increased consumption of and education about specialty crops.

The 22 K-8 schools in the FTS program also benefitted from enrichment opportunities such as field trips, farmer classroom lessons and guest chef visits that they would not have had without the program.

Seventeen specialty crop farm partners participated in portions of the project over the course of the grant and benefitted from selling produce, contracting for field trips and farmer classroom visits and from the connections made with schools, students and families to support long-term demand and preference for their products. 7,043 students, 22 schools, and 4 high schools benefitted from the project's accomplishments.

From 2016-2018, the NJUHSD Food Service purchased $3,995.88 of local and regional specialty crops directly from farmers for school meals, from a baseline of $0. The total percentages of food service money spent on local and regional farmer-direct purchased specialty crops were 5 percent and 6 percent annually, an excellent increase from 0 percent.

The five partner specialty crop farmers who reported gross sales data showed a combined increase in sales of $49,347 in one year during the grant. For small, disadvantaged, specialty crop growers, the average increase in gross sales of 10 percent shows excellent progress toward increased sales and consumption of local specialty crops promoted by the FTS program through this grant.

Lessons Learned

During the growth of the FTS program the survey questions evolved. The version of the HOTM survey used during this grant was a simple, efficient way to measure the changes in student preferences for specialty crops: Teachers record the number of students in their class, ask students to "Raise your hand if you liked (specialty crop item being sampled) before today" and record this number. After the students have sampled, the teachers ask, "Now, raise your hand if you like (specialty crop item being sampled) now", and record this number. Because the teacher only has to record three numbers, it is a simple way to collect data every month.

Over the course of the project it became evident that not all schools want to participate in all FTS project activities, and in order to maintain enthusiastic long-term participation, the FTS program will begin to allow schools more flexibility to tailor the program to their priorities after the grant ends.

Due to the unpredictable nature of farming specialty crops there were times that the planned featured produce item for HOTM had to be changed at the last minute, due to partial crop failure, inadequate yield or insufficient size or quality. It has been challenging for small specialty crop farmers to grow the large quantities need for HOTM for delivery (enough for 7,000 students) on a set date, all at once. This issue could be alleviated by spreading out the dates of HOTM delivery and tasting for different schools.

There have also been ongoing challenges scheduling field trips and farmer classroom visits, and most of the schools who were able to take full advantage of the field trips scheduled them well in advance, asking teachers to confirm dates in May for the following Fall.

The project's attempt to promote specialty crop farmers through coupons for farmers' markets did not result in significant coupon redemption and was not an effective way to increase specialty crop sales to participating families.

One of the lessons learned was about the variability of survey data and setting targets too high. Students' preferences for the different specialty crops can vary widely depending on the item, so expecting 90 percent of students to like a specialty crop item after sampling it was not a realistic target.

Additional Information

1. Sierra Harvest Website:
   https://sierraharvest.org/

2. Harvest of the Month TASTING SURVEY:
   HOM Tasting Survey

   Featured Produce Item: _____

   School: _____ Teacher:_____Grade: _____

Number of students in class: _____

(Before tasting) Raise your hand if you liked *featured produce item* before today: _____

(After tasting) Now, raise your hand if you like *featured produce item* now: _____

* Please return form to your Farm to School Liaison with your ChicoBag. Thanks!
For extra credit, please jot down cute kid quotes about the Harvest on the back ☺

3. HOM newsletter sample – Attachment 1

4. Real Kids Real Food Teacher Testimonial:
"I teach three and four-year old's in the preschool program at our school. I grew up being a produce manager's daughter never eating anything green. I never ate fruits and veggies even into my adult life and with young kids. I would not even buy them at the store.

Sierra Harvest's farm to school program gave me the opportunity to try new fruits and vegetables as an adult and teacher. Last year for the first time I tried mandarins. My oldest son has fallen in love with sugar snap peas. It's all due to Sierra Harvest. My son showed me where they are in the grocery store and the best part is SH forcing me to try these things, it not only gets me to try them but I'm now having my students try them. I now get to talk to the parents in person and via email about the tastings. I never liked bell peppers or turnips before. My husband eats everything and I can cook with bell peppers now. I've given up on my childlike impression of NO! to fruits and veggies. Sierra Harvest has helped in my own house and in the classroom."

5. Real Kids, Real Food program photos – Attachment 2

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
18	Bring the Farmer to Your School: Farm to Family	
Grant Recipient: Sustainable Economic Enterprises of Los Angeles	**Grant Agreement No.:** SCB15018	**Date Submitted:** December 2018
Recipient Contact: Rachel Marks	**Telephone:** (323) 463-3171	**Email:** rmarks@see-la.org

Project Summary

The 2013 California Children's Healthy Eating and Exercise Practices Survey (CalCHEEPS) cites fruit and vegetable consumption for low-income children ages six to 11 at almost one cup below the recommended minimum, with fruit juice making up nearly a quarter of that total intake.

The Bring the Farmer to Your School (BTFTYS) project addresses these negative public health trends by improving nutritional awareness of students, and increasing consumption of California specialty crops. This program, the only one of its kind in Los Angeles County, is focused on parent outreach designed to reinforce student comprehension and further connect families to California specialty crops, as well as a Harvest of the Month (HOM) component that includes produce and educating materials. Childhood obesity, in part due to low fruit and vegetable consumption is an ongoing issue in California's low-income youth.

Without significant and timely intervention focused on reversing these trends, California children will continue to experience increased risk of serious health problems, including heart disease, Type 2 Diabetes, and certain cancers. Targeted nutrition education focused on school-age children may be the most successful means of affecting long-term positive behavior changes leading toward reduced risk of chronic diet-related disease. Small gains in fruit and vegetable intake has positive impacts; according to the November 2014 Journal of the Academy of Nutrition and Dietetics, Latino children ages six to 11 in Southern California saw lowered rates of obesity and improved health indicators with the small addition of fruits and vegetables.

The CalCHEEPS study further links home and school environments as strongly influencing health behaviors for children. Accesses to favorite vegetables as well as family meals are related to increased fruit and vegetable consumption. The study also found that engaging parents in obesity prevention for young children negates declining rates for healthy lifestyle outcomes in older children. A recent United States Department of Agriculture (USDA) report to Congress on direct-to-consumer trends found decreased Southern California sales. Each level of this program stresses the importance and benefits of buying California specialty crops. Ongoing, hands-on education for low-access families boosted specialty crops through overall increased knowledge, purchasing and consumption. A comprehensive educational experience that uses food and farming as an opportunity to teach about not only nutrition, but many core curricular areas including mathematics, science, language arts, social studies and history can be an effective approach toward enhancing both student health and academic performance.

This project built upon the 2013 Specialty Crop Block Grant Program Project 38: *Bring the Farmer to Your School Program*. In the previous project, Sustainable Economic Enterprises of Los Angeles (SEE-LA) had successfully served 164 schools and 80,355 students through farmer presentations, with an emphasis on

exploring agriculture as a career and highlighted by a curriculum about specialty crop production and the benefits of consuming fresh local produce, leading to purchase and consumption of these crops.

Using the positive feedback and results from the previous project, project staff expanded the BTFTYS program. With the continuation of the project's partnership with Sentient Research, a professional evaluation team, SEE-LA engaged to closely monitor results of the progress and understanding and application by students of the curriculum. Resulting evaluation for the program found that students achieved significant increased preference toward some varietal fruits and vegetables, and increased consumption and preference of produce at home. The 2015-2017 farmer presentations and the overall focus included more educational opportunities about production and the nutritional benefits of specialty crops, through expanded outreach to include "the whole family" approach.

SEE-LA continued to be the exclusive provider of this service in Los Angeles County, and built on the previous project's strong achievements by expanding outreach to families, adding parent participants at preschools and elementary schools to the project's scope to fortify training from farmer presentations at Los Angeles Unified School District (LAUSD) schools. Including the addition of parents and caregivers in the equation is vital, because they make the food buying decisions in the household. Parents at the elementary level had access to the presentations in two ways: (1) observation of BTFTYS classroom presentations, and (2) classes in parent centers that focused on similar themes of farming and nutrition, with an additional emphasis on purchasing and preparing fruits and vegetables. Parents of preschool age children had the opportunity to connect to their child's lesson through comparable materials on specialty crops provided through HOM, in addition to HOM produce at early learning centers. Both types of parent outreach gave parents the additional opportunity to continue talking with children at home about specialty crops as part of a healthy diet or other lessons learned. SEE-LA's direction of inclusion worked to connect families through ongoing education about fruits and vegetables directly aided in the promotion, purchase and consumption of these specialty crops in low-access areas.

Project Approach

During the timespan of the project, 142,008 students received a 30-minute presentation about good nutrition, tied to California specialty crops, and California specialty crop careers from a farmer educator or educational farmstead from one of 13 local farmers about specialty crops at 200 schools. Additionally, 1,960 school staff and 7,405 parents attended the presentations. For HOM, 2,001 students and 248 school staff received a sampling of fresh local specialty crops.

In the timespan of the project, The Program Coordinator (PC) focused on:

1. Identifying Title I LAUSD schools for participation
2. Scheduling farmer-led specialty crop presentations
3. Coordinating pre- and post-surveying of students and parents
4. Procuring and coordinating delivery of produce for HOM
5. Tracking the number of presentations, number of students, and number of schools served
6. Receiving and record verification forms
7. Collecting teacher evaluations of the farmers' presentations
8. Observing and review farmers' presentations
9. Recording pre- and post-survey responses filled out by parents attending a specialty crop presentation

The ultimate project goal was primarily focused on educating 160,000 LAUSD students, going to 200 Title I schools, and teaching 900 parents. Under the oversight of the PC and working closely with a retired nutrition educator and teacher from LAUSD, the project began by working with LAUSD administrative staff to execute a Memorandum of Understanding (MOU) to provide access to LAUSD campuses to farmers for presentations.

At each target school, a Lead Teacher and the Principal were contacted and recruited to assist with presentation scheduling, coordination, and evaluation activities. Lead Teachers were sent welcome orientation letters in November 2015- January 2016, and again in August 2017- September 2017 to begin the process of scheduling farmer presentations. Once Lead Teachers responded and expressed interest in participating in the program, the PC sent updated program scheduling and verification forms to begin the process of scheduling farmer visits for each participating school.

SEE-LA in partnership with LAUSD had successfully re-established and expanded the BTFTYS program. Between October 2015 and January 2016, farmers were contacted and recruited to act as educators in the school system, about 130 schools were emailed or faxed a welcome letter to discern interest and a training orientation for the farmer educators was held. Orientations provided farmers with the most recent nutrition education guidelines as well as a list of specialty crop careers to present to students at each presentation. Farmer educators were also required to offer samples to all students of a wide variety of produce, many of which would be new and unknown to students, and to encourage increased daily consumption of California grown specialty crops. In addition, at the orientations, program staff discussed administrative requirements, including Livescan fingerprinting and timely submission of documentation.

The farmers began to teach at the schools in late January 2016 and the school visits held steady going forward. The farmer visits were on brief hold during July 2017 and resumed in August 2017, in alignment with the academic calendar’s scheduled break.

SEE-LA was able to establish a successful partnership with the Urban and Environmental Policy Institute (UEPI), through the innovative HOM program, commencing in May 2016. The program was a collaborative pilot between SEE-LA, UEPI, and Pacific Asian Consortium in Employment (PACE). SEE-LA was able to serve 2,001 students and 248 school staff with a focus on taste testing a new specialty crop each month. At the conclusion of the program, partners were able to discern lessons learned and evaluate barriers to a successful HOM program, such as school budget limits and student dietary concern. Successful HOM programs were able to connect produce to ongoing curriculum and lesson plans and introduced preschoolers to new tastes, textures and vocabulary with their discovery and exploration of the month’s featured specialty crop. Teachers who completed surveys were positive, ranking their experience between 7.0 and 10.0 with an average response of 9.3 (out of a 10.0 scale).

In early November 2016, SEE-LA project staff worked with Sentient Research, evaluation consultant, to design program evaluation materials gauging success at achieving measurable outcomes of project success. Sentient Research’s baseline surveys of 985 third through sixth grade students were collected October 2016 through March 2017 and follow-up surveys by Sentient Research in May 2017 were administered one week prior to the farmer’s next classroom visits yielding 1,042 follow-ups collected. Follow-up (“end-line”) student surveys, as well as farmer educator and Lead Teacher evaluations, were also conducted in May 2017.

Due to the documented results of the surveys and feedback of the presentations from school staff, project staff have seen the long-term positive outcomes and met performance goals for the project, BTFTYS. The project is inherently valuable because most schools do not have extra funding for programs such as BTFTYS, nor immediate access to agriculture-education related opportunities; and, the lessons from a trained local farmer directly to an LAUSD student are unique experiences. The parents and teachers were happy to see the effects of this program, because it has the ability to connect the students to where their food comes from through interactive explanations, visuals, and tastings.

Since all farmer educators are California specialty crop growers, only California-grown specialty crops were provided as samples to students. Farmer presentations were reviewed by project staff to ensure that all content, included only information about California specialty crops. Evaluation materials also reflect only those produce items which were 100 percent related to specialty crops.

A retired nutrition educator and teacher from LAUSD served as SEE-LA's School Liaison for this project. The School Liaison's experience as well as their long-term involvement with BTFTYS was integral to the project's success as they assisted in training the farmers, reinforcing material, scheduling school visits and planning HOM. The School Liaison additionally helped to provide the necessary coordination and communication among the Lead Teachers, Farmers, PC, and other SEE-LA staff. Participating farmers continued to update and improve their presentations to include the latest dietary guidelines and information about California specialty crops.

SEE-LA, in partnership with the UEPI and PACE, worked together to plan a pilot HOM program. SEE-LA coordinated distribution of produce with farmers to education sites, UEPI structured and oversaw partnerships and planning of the program, and PACE provided connection to school sites as well as a preparation kitchen for produce that needed to be processed and prepared for samples. UEPI gathered findings and has drafted a Farm to Preschool guide that is pending distribution.

Sentient Research was an effective and cooperative partner, aiding in evaluating the impacts of BTFTYS. The primary role of Sentient Research was the creation of, through collaboration with SEE-LA project staff, pre-and-post surveys/tests to be used in accurately capturing measurable outcomes and then compiling them into a final report. Project staff relied on their experience working with all academic levels in best practices in order to yield clear and concise data – baseline and final.

Goals and Outcomes Achieved

The PC worked with the School Liaison to identify 200 target schools and Lead Teachers to assist with scheduling farmer visits at schools. Through the term of the project 142,008 students received a presentation from one of 13 local farmers about specialty crops at 200 schools. Additionally, 1,960 school staff and 7,405 parents attended the presentations. For HOM, 2,001 students and 248 school staff received a sampling of fresh local produce. All of the schools that participated received a hands-on, interactive 30-minute lesson or farmstead about good nutrition related to California specialty crops. Sentient Research worked with the PC and Program Manager (PM) to design evaluation tools (student, teacher, and farmer surveys), and administered pre-tests to students in October 2016, with follow-up post-tests until the end of May 2017.

The outcome measures for the project were short-term, and focused on the changes in students' knowledge and behavior from the pre-test administered as early as (September 2016) and post-test administered as late as (May 2017).

The project goal was to influence main outcomes, primarily that 160,000 students and 900 parents at 200 Title I schools would gain an improved understanding of the essential importance of increasing consumption of fresh fruits and vegetables to help combat and prevent serious potential health problems linked to diet-related disease, and by extension purchase more of these specialty crops.

The project served 142,008 students, falling short of the project goal of 160,000 students. Farmer presentations about specialty crops were conducted at 200 Title I schools, and achieved the project goal of 200 Title I schools. There were 380 parents that attended parent specific classes, and over 7,405 parents attended the student's presentations compared to the goal of 900 parents, significantly exceeding the project goal.

The project's evaluation showed data significance in students knowing and liking specific specialty crops that they had not previously tried (such as beets, kale, and persimmons). Results indicated that students tended to remember produce that they had tried and liked, and this was linked specifically to produce brought by the farmer. This evaluation insight connected to SEE-LA's goal to introduce students to specialty crops and increase their enjoyment of the fruits and vegetables that they tried, thus proving the project's model a success.

Baseline and follow-up questionnaires were collected from students in 44 classrooms in seven elementary schools that received visits from a local farmer from the BTFTYS program. For each class at baseline and follow-up, the evaluator distributed the survey instrument and provided the same instructions to each class. The evaluator read the questions and response options aloud, as appropriate, as students filled out the survey instrument. Students were asked to raise their hand if they had any questions and were asked to complete the assessment silently without sharing responses aloud to prevent bias. One thousand ninety-four (1,094) baselines were collected one week prior to the farmer's visit; 1,042 follow-ups were collected in May 2017, taking place one month after the farmer's visit in the classrooms. The *Farmer in the Classroom* student survey instrument was designed to collect a host of measures relevant to program outcomes among elementary school students. The questionnaire measures were designed to assess key outcomes that included the consumption of fruits and vegetables, the availability of fruits and vegetables at home, and appeal for different fruits and vegetables. Nine hundred eighty-five (985) baseline and follow-up questionnaires were matched and statistical analysis (basic descriptive and Wilcoxon rank-sum tests) for paired samples was conducted to assess changes in key outcomes before and after the farmer's visit in the classroom.

Participating teacher perspectives on the program were collected as well. A teacher survey instrument was administered before each farmer visit to the participating head teachers who attended each farmer presentation.

A summary of the evaluation report's findings is below:

- *Food Preference Questionnaire:* These results illustrate the tendency for students to remember new fruits and vegetables that they have an opportunity to try and find them appealing. This was especially the case for persimmons, kale, swiss chard, and tangerines.

The farmers visiting the classrooms brought these items and likely introduced many students to them for the first time.

- *Fruit and Vegetable Consumption Preference*: Between baselines to follow-up, there was a significant overall increase in liking to eat fruits as snacks, and a significant overall decrease in liking to try new vegetables.
- *Access to Fruits and Vegetables at Home:* An increase was observed among students for having both fruits and vegetables to eat at home from baseline to follow-up specifically in the category of "always". No results were statistically significant; however an increase in having vegetables to eat at home almost reached significance.
- *Parental Consumption of Fruits and Vegetables at Home:* The majority of students indicated requesting a specific food item the last time they went grocery shopping with their parent, but no significant differences were observed between baseline and follow-up. When a food item was requested, most students asked for fruits. There were no significant nor meaningful changes between baseline and follow-up in regard to specifically requesting fruits, vegetables, or other foods.

Beneficiaries

Students at LAUSD Title I schools and the specialty crop farmer educators presenting at those schools were the project beneficiaries. Through SEE-LA's unique program, farmer educators offered samples of a wide variety of produce, many of which were new and unknown to students, and encourage increased daily consumption of California grown specialty crops.

There were 142,008 LAUSD students at 200 Title I schools received a unique presentation from a local farmer teaching about the nutritional benefits of eating more fruits and vegetables and farming as a career. Students showed a significant increase in knowledge of having vegetables to eat at home and preference for trying new fruits and vegetables.

Lessons Learned

The project timeline originally planned to begin the BTFTYS visits as early as November-December 2015, once participating schools had been identified. However, due to delays in executing the MOU with the LAUSD, the first farmer visit did not take place until January 2016. Between October 2015 and January 2016, farmers were contacted and recruited to act as educators in the school system, approximately 130 schools were emailed or faxed a welcome letter to glean interest and a training orientation for the farmer educators was held.

The two to three hour orientation with new farmer-educators and current educators proved to be very effective, as it has been in past program cycles. In the future, SEE-LA would like to have even more time with farmers-educators to specify and review their presentation material, both before classroom visits begin and throughout the school year. This can be somewhat difficult to schedule, as most farmer-educators are coming from long distances and are very busy, but project staff believe this would likely be worth the extra effort and time.

Ultimately, the project evaluation showed the program's most resonant impact on students' remembering fruits and vegetables they'd been exposed to through the program and that they were more likely to expand their palates when introduced to new varieties of produce.

During the previous project of BTFTYS, the program gained exposure to other organizations working on nutrition educated-related issues in Los Angeles County and with LAUSD. In particular, the Los Angeles County Department of Public Health Nutrition Education Obesity Prevention program learned of the BTFTYS program due to overlapping programming at a small number of LAUSD schools.

Another positive unexpected outcome was the incorporation of garden education, and garden development with the farmer-educators' lessons at some school sites. Schools that had school gardens, or were just starting to build one, were significantly more invested in the project goal, and students at these schools seemed to have more foundational knowledge of specialty crops and nutrition education, and therefore got more involved in the farmer-educator's lesson.

The only outcome measure that was not fully achieved was the number of students served. The project goal was 160,000 students, and the actual number served was 142,008 students. Project staff believe that the reason for not achieving the projected goal was due to the logistics of the ending and beginning of the school year causing a delay in response. For future projects, SEE-LA will factor in the understanding that it might take longer for schools to respond and schedule visits at the beginning and ending of school years.

Additional Information

SEE-LA has provided the final "Student Impact Evaluation Report" conducted and authored by Sentient Research.

Additional information about the BTFTYS program can be found at the SEE-LA website: http://seela.org/bring-the-farmer-to-your-school/

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 19	**Project Title:** Increasing Specialty Crop Consumption through increased WIC Farmers' Market Nutrition Program Check Redemption	
Grant Recipient: Pacific Coast Farmers' Market Association	**Grant Agreement No.:** SCB15019	**Date Submitted:** December 2018
Recipient Contact: Laura deTar	**Telephone:** (925) 825-9090	**Email:** lauradetar@freshapproach.org

Project Summary

In 2014, when this project was proposed, California Women, Infants, and Children (WIC) agencies distributed more than $2.4 million in WIC Farmers' Market Nutrition Program (FMNP) checks that could only be spent on fruits, vegetables, or fresh herbs at certified farmers' markets, but only 68 percent were redeemed. The unredeemed checks represent more than $775,000 of lost revenue for California specialty crop farmers. This project aimed to increase the redemption rate of WIC FMNP checks in the Bay Area by partnering with WIC agencies to conduct check distribution at farmers' markets instead of at the WIC agency sites. Recognizing that many WIC recipients are not current farmers' market shoppers, the project also provided WIC recipients with free classes to help them learn how and where to use the checks and how to increase their fruit and vegetable consumption on a budget.

WIC FMNP is the only public food assistance program that exclusively benefits California specialty crop farmers. Checks may only be used at certified farmers' markets to purchase fresh fruits, vegetables, and cut herbs. This project encouraged families who receive WIC FMNP to spend more of their WIC FMNP checks, and to continue to shop at farmers' markets with CalFresh/SNAP or other food dollars after they have spent the FMNP checks. As direct-to-consumer sales of food at farmers' markets have slowed in recent years (United States Department of Agriculture, 2015), it is crucial that the specialty crop industry engages with a broader customer base.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The activities completed during this project all aimed to increase the purchasing and consumption of California certified specialty crops in families who receive the WIC FMNP coupon booklet, to increase the redemption rates in the Bay Area. One of the primary project activities included completing a total of 42 nutrition education classes at local WIC sites teaching the importance of specialty crops to a healthy diet, food budgeting and farmers' market shopping tips. Classes involved a short lesson and recipe tasting and discussion. Class attendees received Farmers' Market Cookbooks and completed post-surveys at the end of each class. The other primary project activity was completing a total of 62 WIC FMNP coupon booklet distribution events at local certified farmers' markets – and additional 35 distribution events occurred at farmers' markets in the months directly after the project ended. The FMNP distributions involved: WIC staff distributing paper invitations to WIC families in the weeks leading up to the event; Pacific Coast Farmers' Market Association (PCFMA) staff coordinating the booth space with market managers and internal staff who supported the events on site; at least two WIC staff members preparing materials in their offices and coming to the nearby farmers' market with table cloths, educational materials, FMNP coupon booklets, and proper WIC tracking mechanisms (paper logs for recording, or laptops with hotspots to input information directly into the system); PCFMA staff setting up a WIC booth space including a shade canopy, table and chairs, WIC

FMNP banners, and providing extension cords or other supplies as available and needed by WIC staff during the distribution; and then between five and 350 WIC families coming to the farmers' market to receive their FMNP booklets. WIC staff would use the booth space for three to four hours distributing between $100-$7,000 in one day, helping to boost specialty crop farmers' income. At distribution events, PCFMA staff also provided on-site nutrition education, FMNP booklet use instructions, collected survey data and distributed Farmers' Market Cookbooks to WIC families. At times, 50+ families were in line waiting to receive their FMNP checks, and PCFMA staff would utilize that waiting time to talk more deeply with families about all the specialty crops available at the market, offering tips and recipes specific to the specialty crops available that day.

The nutrition classes and distribution events had impressive impacts engaging thousands of local WIC families to spend their WIC benefits and other food dollars at local farmers' markets, creating a lasting increase in farmers' market customers to support specialty crop farmers.

Other activities helped support the success of the nutrition classes and distribution events. Project staff spent time and supplies developing and revising the Farmers' Market Cookbook which compiled recipes and nutrition information to show how to stretch $20 in WIC FMNP or other food dollars into multiple healthy meals for families. The Cookbook includes kid-friendly recipes for both traditional meals and healthy snacks, as well as tips on how to shop seasonally on a budget and cooking in bulk. This Cookbook will be utilized, revised, and expanded long after the project timeline to encourage more low-income shoppers to spend their food dollars at local certified farmers' markets.

Some activities included administrative duties that helped make the primary project activities possible: maintaining WIC FMNP certifications for all PCFMA farmers' markets and market managers and tracking the spending of WIC FMNP coupons at PCFMA farmers' markets. The administrative activities helped create a welcoming environment for WIC families to use their food assistance benefits to purchase local specialty crops.

Oher activities helped evaluate and maintain the impacts of this project long after the timeline completed: meeting with WIC clinic partners to plan activities and maintain partnerships; developing, implementing, and analyzing data from project assessment surveys; assessing potential economic impacts of the project; and developing best practices guides and presentations for interested partners throughout the United States (U.S.).

Significant results from these project activities include: a 40 percent increase in WIC FMNP coupon redemption at PCFMA farmers' markets over the two years of project implementation; four County and one non-profit WIC agency partners participated in multiple years of FMNP distributions and nutrition classes that resulted in project impacts being felt across 15 different WIC agency sites in Alameda, Contra Costa, San Mateo, Santa Clara, and Solano counties; and a commitment from farmers' market operators and WIC sites to continue hosting and distributing WIC FMNP checks at certified farmers' markets for years to come.

The major conclusions and recommendations that have resulted from this project are being shared widely with WIC agencies and farmers' markets around California and the U.S.

The overall scope of this project was to increase the redemption rates of WIC FMNP coupons, which can only be spent on specialty crops at certified farmers' markets. The only activities conducted during the project period were those using staff time. Staff time was used to conduct research on current redemption rates; to connect with partner WIC clinics and county WIC Directors to plan nutrition education classes and FMNP distribution events, and to implement classes and events; to analyze survey results; and to track and report on the progress of this project. These activities were completed with the sole purpose of enhancing the competitiveness of specialty crops by increasing the redemptions of WIC FMNP coupons.

WIC site partners through the Bay Area partnered with PCFMA to distribute FMNP checks at farmers' markets and to host classes at their WIC sites, contributing significantly to this project. By dedicating their staff time to distribution FMNP checks at farmers' markets, redemption rates for their sites increased, and WIC partners were encouraged to continue and improve their efforts in the coming season's activities. The Contra Costa County WIC sites and Gardner Family Care WIC sites helped develop a template for a farmers' market educational activity that WIC families complete at the WIC clinic before receiving an invitation to come to the farmers' market to receive their FMNP checks. These WIC partners have also helped develop and adapt a paper invitation that reminds WIC families to come pick up their FMNP checks at the farmers' market with specific date and location instructions. WIC partners also dedicated staff time to place reminder phone calls to families who received the paper invitations, reminding them to come to the farmers' market on a specific date to pick up their FMNP checks. Both the in-market activities and the FMNP distribution invitation were then shared with WIC staff in other counties to help with their FMNP distribution events. These materials are used as a model for how WIC agencies can make it easy for both their staff and their client families to utilize the FMNP checks.

Goals and Outcomes Achieved

The first goal for this project was to increase WIC FMNP redemptions in the San Francisco Bay Area. To that aim, WIC FMNP redemption data from 2015, prior to the implementation of PCFMA's nutrition classes and distribution events, was analyzed by the project manager to determine where to focus education and outreach efforts in the first year of this project. Partner WIC clinics in the San Francisco Bay Area known to the project manager to currently distribute WIC FMNP checks at local farmers' markets, where those checks can be immediately redeemed, were seen to have WIC FMNP redemption rates above 73 percent in 2015. Whereas partner WIC clinics in the area who are known not to distribute WIC FMNP checks directly at farmers' markets saw redemption rates between 40 percent and 58 percent. Efforts in year one of this project targeted clinics that had redemption rates in the latter category, and where the project manager had established partnerships. Efforts in year two of this project focused on building the success of the WIC clinic partners from year one, as well as beginning to partner with a new WIC county agency. Specifically, WIC clinics operated by Contra Costa County Health Services, Solano County WIC, Gardner Family Care, and San Mateo County Department of Public Health were targeted for partnership in the first year of this project, and for deeper sustained partnership in year two. Year two also saw the project expand to include WIC sites operated by Alameda County, which had a 2016 redemption rate of 51 percent.

Data from the California State WIC Office was released in February 2018. Contra Costa and Solano County distributed 100 percent of their 2017 FMNP coupons directly at farmers' markets, seeing 75 percent and 87 percent redemption rates respectively. In 2015, Contra Costa distributed all their WIC FMNP booklets from their office sites and had a redemption rate of 42.5 percent - showing the dramatic difference that can be made quickly by distributing all WIC FMNP checks directly at farmers' markets. Alameda County, Gardner Family

Care, and San Mateo County all distributed a small portion of their FMNP coupons directly at farmers' markets in 2017 – but even the small amount made differences for the sites that distributed FMNP directly at farmers' markets. Alameda County saw their FMNP redemption rate increase by 2 percent, San Mateo County saw redemption increase by 3 percent, and Gardner Family Care saw redemption increase by 8 percent. These three partners were all inspired by the small efforts they put in and the direct correlation to increased redemption that they saw in 2017, as a result they all committed to distribute as many of their FMNP checks as possible at local farmers' markets in 2018.

The second goal of this project was to increase specialty crop consumption amongst WIC FMNP recipients. Surveys collected from WIC families at classes and distribution events indicated that 80 percent of participants learned a lot about shopping at farmers' markets, 73 percent learned a lot about how to select and store fresh produce, 86 percent learned a lot about ways to include more healthy foods in their diets, and 81 percent learned a lot about why fruits and vegetables are good for them. Survey results also indicated that 88 percent of respondents intended to shop the same farmers' market again that year, and 79 percent of respondents said that knowing their fruits and vegetables are California-grown is important (24 percent) or very important (55 percent) to them. These last two data points indicate that WIC families are primed to continue shopping at local farmers' markets, and represent a valuable customer base for specialty crop farmers who sell at certified farmers' markets.

The third goal of this project was to create a system for sustaining impacts after this project ends. That system engaged with WIC agency partners on an annual basis to recruit new partners and refine practices with current partners to continue distributing WIC FMNP coupons directly at certified farmers' markets, and encouraging WIC families to spend the $20 in their booklet that day and then return to the market again later that year to use their CalFresh/SNAP or other food dollars to buy fresh local specialty crops. PCFMA has developed partnerships with a wide array of farmers' market operators during this project to increase redemptions of FMNP coupons overall, and to help WIC agencies connect with the farmers' markets serving their community to distribute the FMNP booklets. WIC agency partners can now connect directly with market managers and farmers' market operators to plan distributions at the local certified farmers' market closest to the WIC site. WIC clinic and agency partners from this project have all committed to distribute nearly all their FMNP coupons at farmers' markets in 2018, and all contacted the project manager directly in 2018 instead of waiting to be contacted about the FMNP distributions. WIC agencies have an incentive to keep their FMNP coupon redemptions high because the higher their redemption rate, the more FMNP coupon booklets their agency will be allocated from the State WIC agency the following year. Local WIC agencies do not receive enough FMNP coupon booklets for their thousands of clients in their service area, so they are always looking for ways to bring more services to the residents they serve.

Many of the impacts of this project will be sustained long after the project ends due to the partnerships and systems created during this project. Farmers' Market Managers and WIC clinic partners are prepared to implement WIC FMNP distributions directly at farmers' markets every year as a part of their regular protocols. With market managers and WIC clinic partners contacting each other directly each year, and market managers offering WIC partners free booth space with a canopy and table (when available) for their staff to distribute FMNP coupons at the farmers' markets. This simple system makes it easy for each party to maintain within the boundaries of their normal operations.

Survey responses received from WIC clinic partners revealed that they are primed and excited to continue the impacts of this project. Bay Area WIC clinics with 2017 WIC FMNP redemption rates of 50 percent and below were also surveyed to determine their interest in distributing their WIC FMNP coupon booklets at local farmers' markets to increase their FMNP redemption rate. New and current WIC partners will continue to be managed by the community-based programs team at PCFMA; connections will continue to be made with market managers to help increase FMNP coupon redemption rates further; and presentations and technical assistance will continue to be provided to WIC agencies and organizations across both California and the U.S. to sustain the impacts of this project. The overarching aim of this project (to increase the customer base for certified specialty crop farmers) is very close to PCFMA's organizational mission (to make California farmers' enormously successful), and the best practices developed during this project will be continued long after the project ends.

WIC FMNP Coupon redemption rates have increased 40 percent at PCFMA farmers' markets over the course of this project, with steady growth each implementation year. In 2015, a total of $75,815 in WIC FMNP coupons were redeemed; In 2016, year one of PCFMA regularly hosting WIC at markets and offering nutrition classes at WIC sites, $91,112 in WIC FMNP was redeemed; and in 2017, $105,950 in WIC FMNP was redeemed. This data shows that Goal 1 of this project, "Increase WIC FMNP redemptions in the San Francisco Bay Area," was achieved.

Goal 2 of this project, "Increase specialty crop consumption amongst WIC FMNP recipients". WIC families completed surveys after the one-time interaction with PCFMA staff at either a WIC FMNP distribution event or a nutrition and cooking class at a WIC site. Because of the drop-in nature of these interactions, PCFMA staff assessed intent to increase consumption via surveys and saw 80 percent (aimed for 70 percent) of nutrition class and distribution event participants learned a lot about shopping at farmers' markets, 73 percent (aimed for 75 percent) learned a lot about how to select and store fresh produce, 86 percent (aimed for 80 percent) learned a lot about ways to include more healthy foods in their diets, and 81 percent (aimed for 85 percent) learned a lot about why fruits and vegetables are good for them. Survey results also indicated that 88 percent of respondents intended to shop the same farmers' market again that year, and 79 percent of respondents said that knowing their fruits and vegetables are California-grown is important (24 percent) or very important (55 percent) to them. These results, in combination with the increased spending in WIC FMNP coupons during the project years indicates a high likelihood that WIC families are increasing their fruit and vegetable consumption, and will continue shopping at local certified farmers' markets.

Results from surveys of WIC FMNP recipients showed exciting trends in shopping behaviors and preference to local products. Responses indicated that 74 percent of WIC families had shopped a farmers' market in the past six months; with 12 percent shopping at the farmers' market every week, 30 percent shopping once or twice a month, and 31 percent shopping a few times in the past six months. Surveys also indicated that 88 percent of respondents intended to shop the same farmers' market again that year, and 79 percent of respondents said that knowing their fruits and vegetables are California-grown is important (24 percent) or very important (55 percent) to them.

These results point to the most exciting and quantifiable result from this project: WIC FMNP check redemptions at PCFMA farmers' markets saw a 40 percent increase over the course of this grant term, equating to a $30,000 increase in spending from 2015 to 2017. The combined increase in spending FMNP

coupons, and the survey data above indicating that WIC families are becoming more regular farmers' market shoppers who are placing a high value on California-grown specialty crops, show great promise for low-income families becoming more regular shoppers at certified farmers' markets that accept food assistance benefits. This outcome has the potential to help local specialty crop farmers expand their incomes exponentially – if 88 percent of families who spent WIC FMNP coupons returned to the market just one time to purchase the same amount of specialty crops, farmers would earn another $26,400.

Beneficiaries

There are two primary beneficiaries of this project: California certified specialty crop farmers were the primary beneficiary of this project with a total increased income of $30,000 over the projects' two years; families receiving WIC FMNP coupon booklets received additional education and recipe ideas to encourage regular specialty crop purchases and consumption. Additional beneficiaries are WIC agency sites, who benefited by receiving more FMNP coupon booklets for their clients as their redemption rates increased; and PCFMA received valuable insights in best practices for engaging with community partners and WIC families.

More than 10,000 residents were directly impacted by their family receiving and spending the WIC FMNP coupons that their WIC agency distributed at local certified farmers' markets. Over 200 specialty crop farmers saw an immediate economic impact from the FMNP coupons being spent on their specialty crops. Ultimately, specialty crop farmers will see a continuously increasing economic impact as WIC families continue to shop and use their benefits to purchase specialty crops.

Lessons Learned

One of the biggest lessons learned in this project was to be flexible in how the project is implemented, and in the materials created. As time passed in this project, staff received feedback on the Farmers' Market Cookbook from WIC families and WIC agency staff that helped shape and guide the final product (Attachment 1). The current iteration of the Cookbook has received very positive reviews from WIC families and the draft will continue to evolve over time. This flexibility with personnel time to create the most useful materials for program participants – not just the easiest using existing materials – provided a long-lasting tangible tool as well as an educational experience for project staff.

Farmers' market operators should keep in mind that WIC families represent many who also receive CalFresh/SNAP benefits, so there is potential for gaining new repeat customers to their markets, helping to encourage more farmers to attend the markets. If the market manager can investigate the nearby WIC sites, and then request an introduction to the WIC site manager to talk about WIC FMNP, then FMNP distributions will happen at a much quicker pace. If the market manager has the supplies available, providing WIC with a booth set up including a shade canopy, table and chairs, really helps to encourage FMNP distributions by removing this small, but often mighty logistical barrier to WIC staff attending markets.

WIC agencies need to keep in mind that farmers' markets have a variety of variables they are constantly tracking to make sure that the markets are a viable economic option for small and mid-size local farmers to support their businesses. A farmers' market takes care and coordination with counties, cities, farmers, and site hosts to create a robust and welcoming marketplace – so contacting and planning in advance as much as possible makes it easier for farmers' markets to accommodate a WIC booth. If WIC agencies ask with enough notice, market managers can often provide an extra table and shade canopy for their use at the market, or shared table space at the information booth. It is recommended that WIC staff ask the market manager about

these supplies and explain any barriers their WIC site has to bringing large supplies to the market. WIC staff should also ask the market manager to set up the WIC booth next to the information booth that is accepting CalFresh/SNAP, so WIC families can see other food assistance benefits that can be spent at the farmers' market. A good tip for WIC staff building a relationship with their local farmers' market manager is to let them know that WIC staff at the market will also promote the acceptance of WIC Fruit and Vegetable check (a year-round benefit available to purchase specialty crops at certified farmers' markets) and CalFresh/SNAP to their clients – increasing the likelihood that WIC families will return to shop that market again in the year. If both parties put in a small amount of coordination, then achieving the shared goal of WIC FMNP coupon redemption rates increasing every year is very achievable.

The quick and dramatic increase in WIC FMNP coupon redemptions at PCFMA markets – 40 percent increase over two years – was very unexpected for making what seems to be a minor logistical adjustment in how FMNP coupons are distributed.

Additional Information

See Attachment 1.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 20	**Project Title:** Increasing Access to Specialty Crops in Fresno	
Grant Recipient: National Hmong America Farmers, Inc.	**Grant Agreement No.:** SCB15020	**Date Submitted:** April 2018
Recipient Contact: Chukou Thao	**Telephone:** (559) 313-3339	**Email:** cxthao05@gmail.com

The California Department of Food and Agriculture (CDFA) terminated this agreement March 16, 2018 for cause and is currently seeking repayment from the National Hmong America Farmers, Inc. (NHAF) for unsupported costs totaling $116,131.

In April 2017, representatives of NHAF failed to appear at a scheduled site visit. NHAF was unresponsive to efforts by CDFA to resolve this matter and reschedule the site visit. NHAF also failed to provide a biannual progress report due April 30, 2017. CDFA continued efforts to contact NHAF and resolve this matter. When those efforts were unsuccessful, CDFA initiated the process of terminating the agreement in July 2017.

Mr. Chukou Thao, Executive Director of NHAF contacted CDFA after being notified the agreement was being terminated and at his request, the termination was suspended on the condition that Mr. Thao provide the past due report and documentation to support costs incurred on the grant to date.

In August 2017, Mr. Thao provided a progress report that was largely redundant to the NHAF's 2016 annual report and which described costs and activities that were unallowable, including the promotion of Pho in Fresno, CA school lunches and a Thanksgiving turkey giveaway. Mr. Thao also provided documentation to support costs incurred on the grant. That documentation was incomplete, contained irregularities and included receipts for unallowable costs.

Based on the unallowable activities in the report and unallowable costs in the documentation provided by NHAF, the CDFA Audit Office initiated an audit of the agreement in October 2017. The audit found substantial irregularities and unsupported costs of $116,131. A preliminary audit report was provided to NHAF on January 11, 2018. No response was received from NHAF on the preliminary audit report and a final report was published February 15, 2018 (attached). The agreement was terminated on March 16, 2018, after 30 days had passed without a response from NHAF to the final audit report.

NHFA is currently receiving federal funding from other USDA programs, including the National Resource Conservation Service and a recent award from the National Institute of Food and Agriculture Program Beginning Farmer and Rancher Development Program. Based on the audit findings for SCBGP funding, CDFA recommends that the NHFA be reported to the Federal Awardee Performance and Integrity and Information System.

USDA Project No.:	Project Title: Development of Starter Cultures to Obtain Consistent, High Quality Sicilian-style Olives	
21		
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB15021	**Date Submitted:** December 2018
Recipient Contact: Kyria Boundy-Mills	**Telephone:** (530) 754-5575	**Email:** klbmills@ucdavis.edu

Project Summary

California is the only producer of fermented "specialty" table olives in the United States. The national and international market for this product offers strong growth potential to California table olive processors. However, there is currently a lack of methods available to processors to control the fermentations and this deficiency has resulted in an excess of $10 million in product losses, limiting profitability for the sector as well as growth and investment for improvement of specialty table olive production.

The California table olive industry has experienced sporadic and costly spoilage events involving excessive softening of the mesocarp. Through the support of an earlier Specialty Crop Block Grant Program (SCBGP) project, the research team screened hundreds of yeasts that were isolated from these spoiled olives for pectinolytic activity. In one-gallon pilot scale studies, the research team successfully identified a single pectinolytic yeast (belonging to the species *Saccharomyces cerevisiae)* as the cause of the observed spoilage phenotype.

Fermented Sicilian-style table olives have been produced in California for the past century. Processing has been guided by traditional rather than scientific methods. Unpredictable, frequent, and costly spoilage events damage the olive product during fermentation and erode the profitability. Modern biochemical and microbiological methods are needed to ensure the production of a consistent and marketable product. Until this is achieved, losses due to spoilage limit the overall potential for growth, improvement, and diversification of table olive production in California. This project is important and timely because frequent and substantial spoilage events have resulted in heavy financial losses to Sicilian-style olive processors in California. In recent years, multiple tanks of olives valued at $100,000 per tank have spoiled on a regular basis. At the same time, many olive growers have become more dependent upon Sicilian-style processors because of the decline in the market for the California black-ripe (non-fermented) olives. The industry is therefore facing a critical period in which to incorporate modern fermentation and analysis methods.

This project built upon the 2011 SCBGP Project 28: *Reducing Spoilage and Expanding Growth in California Specialty Olives through Improved Fermentation Management*. These earlier phases provided, for the first time, a scientific understanding of normal microbes as well as detrimental spoilage microbes in California Sicilian-style olive fermentations.

Earlier project phases delivered the following results:

(1) Isolated, identified and preserved hundreds of yeasts and lactic acid bacteria from California olive fermentations and commercial spoiled olives to use in the proposed project.
(2) Isolated and identified olive-associated yeasts with pectinase activity.
(3) Shown that yeasts with pectinase activity can cause olive spoilage defects.

(4) Validated that pectinase levels in olive brines can be used as an early-warning system for future spoilage.
(5) Identified late-harvest fruit as particularly vulnerable to spoilage events.

The first three results were published in 2012 (Golomb et al., 2012).

The long-term quantifiable effects of the previous results are that Sicilian-style olive processors in California have, for the first time, implemented protocols to minimize spoilage events. These protocols include eliminating late-harvest fruit from processing and also monitoring fermentation brines for microbial, chemical, textural, and pectinase levels to maintain levels in the range required for normal fermentations.

In summary, the previous work provided several landmark accomplishments the California olive industry. The prior work largely focused on identifying the fundamental attributes of the olive fermentations and validating the roles of pectinolytic yeast in olive spoilage. This new project was a critical and much needed step forward by providing methods to improve and regulate the olive fermentations through starter culture technology and detect the potential for spoilage prior to significant losses of the final product.

Project Approach

Activity 1: Screen and select yeasts and bacteria previously isolated from California olives for promising characteristics including killer activity, lipase activity, oleuropin degradation, salt tolerance and pH tolerance. Select at least six yeasts and bacteria for pilot studies.

Results: Sixty strains of yeasts were screened for killer activity against the spoilage yeast, ability to grow on oleuropein as a sole carbon source, lipase activity, salt tolerance and ability to grow at the low pH of olive fermentations. Also, 41 bacteria belonging to 12 species of lactic acid bacteria were screened for ability to tolerate low pH and high salt. Several microbes were selected for use in pilot olive fermentations:

- Spoilage yeast *Saccharomyces cerevisiae* UCDFST 09-448. This is the spoilage yeast that was determined causes very costly excessive softening of olives in Sicilian-style olive fermentations.
- Candidate starter culture yeast *Wickerhamomyces anomalus* UCDFST 02-204, a “killer” yeast able to control *S. cerevisiae* spoilage yeast in lab experiments on Petri plates. The research team wanted to determine whether this yeast could also control the same yeast when both were added to pilot-scale olive fermentations.
- Candidate starter culture yeast *Candida pelliculosa* UCDFST 40-438, which degrades oleuropein.
- Candidate starter bacteria *Lactobacillus plantarum* AJ11.
- Candidate starter bacteria *Lactobacillus pentosus* OL1, recently developed olive starter culture provided by starter culture company Lallemand. This starter culture was developed in Europe by academic researchers in Italy, and has been commercialized by Lallemand. However, it is optimized for a different style of olives that are fermented at neutral rather than acidic initial pH. The team wanted to see if these bacteria could produce suitable Sicilian-style olives, and/or prevent spoilage by the pectinolytic yeast.

Activity 2: Make improvements to the existing pectinase assay for use in olive processors’ facilities.

Results: Various combinations of dyes and test matrices were explored to improve the assay, and successfully detected pectinase activity in both the brine and olives in the pilot olive fermentations that exhibited spoilage.

This indicates that further improvements of the assay could be useful for detecting early stages of spoilage, before excessive softening has occurred.

Activity 3: Perform trial inoculations of starter cultures in at least six pilot scale olive fermentations, using olives provided by industry partners.

Results: The organisms listed in Activity 1 above were used in pilot scale olive fermentations, using olives provided by industry partners. The research team ran a total of 29 conditions, each in duplicate, over the course of three years, much more than the six conditions originally proposed.

These organisms were used in fall 2015 pilot fermentations of olives, two buckets per treatment:

- 1, 2: Negative control (no microbes added)
- 3, 4: Spoilage yeast *S. cerevisiae*
- 5, 6: Spoilage yeast *S. cerevisiae* + killer, oleuropein degrader, high salt and low pH tolerant yeast *W. anomalus*
- 7, 8: Killer, oleuropein degrader, high salt and low pH tolerant yeast *W. anomalus*
- 9, 10: Oleuropein degrader *C. pelliculosa*
- 11, 12: Spoilage yeast *S. cerevisiae* + killer, salt and low pH tolerant yeast *D. hansenii*
- 13, 14: Oleuropein degrader *C. pelliculosa* + *L. plantarum* AJ11
- 15, 16: Killer, oleuropein degrader, high salt and low pH tolerant yeast *W. anomalus* + *L. plantarum* AJ11
- 17, 18: Lallemand *L. pentosus* OL1
- 19, 20: Lallemand *L. pentosus* OL1 + Spoilage yeast *S. cerevisiae*

Activity 4: Perform trial inoculations in at least six pilot scale olive fermentations, using olives provided by our industry partners.

Results: Initially the research team planned to perform one set of pilot olive fermentations in fall 2016. The pilot fermentations and analysis of olives and brine are very labor intensive, and can only be performed once per year, at harvest time. However, in summer and fall 2015 (not paid for with grant funds) the team was fortunate to have two visiting professors with experience handling olives: one from the University of Turin, Italy, and the other from the University of Split, Croatia. The professor from Italy led a project to screen yeasts, and both professors set up a preliminary set of olive pilot fermentations, one season earlier than planned. Olives were provided by processors in Northern California. None of the selected candidate starter cultures prevented excessive softening.

A second set of pilot fermentations was performed in fall 2016, using olives provided by processors. Ten treatments were tested, each in duplicate, for a total of 20 buckets.

- 1, 2: Negative control (no microbes added)
- 3, 4: Spoilage yeast *S. cerevisiae*
- 5, 6: Spoilage yeast *S. cerevisiae* + killer, oleuropein degrader, high salt and low pH tolerant yeast *W. anomalus*
- 7, 8: Killer, oleuropein degrader, high salt and low pH tolerant yeast *W. anomalus*
- 9, 10: Oleuropein degrader *C. pelliculosa*

- 11, 12: Spoilage yeast *S. cerevisiae* + killer, salt and low pH tolerant yeast *D. hansenii*
- 13, 14: Oleuropein degrader *C. pelliculosa* + *L. plantarum* AJ11
- 15, 16: Killer, oleuropein degrader, high salt and low pH tolerant yeast *W. anomalus* + *L. plantarum* AJ11
- 17, 18: Lallemand *L. pentosus* OL1
- 19, 20: Lallemand *L. pentosus* OL1 + Spoilage yeast *S. cerevisiae*

The research team measured salinity, pH, pectinase activity, olive firmness, and enumerated bacteria and yeast by plating. Unfortunately, none of the treatments were able to prevent excessive olive tissue softening by the spoilage yeast.

The team then tried altering the pH, and also tried the latest version of the bacterial starter culture of *Lactobacillus pentosus* recently introduced to the olive fermentation market by Lallemand called LalOlive Crispy. A third set of fermentations were run in fall 2017, and all the same measurements were made as in the fall 2016 set.

Bucket(s)	Treatment	pH
1 & 2	No inoculation (natural fermentation)	4.5
3 & 4	*Saccharomyces cerevisiae* spoilage yeast	4.5
5 & 6	*Saccharomyces cerevisiae* spoilage yeast with *Wickerhamomyces anomalus* “killer” yeast	4.5
7 & 8	*Wickerhamomyces anomalus* “killer” yeast	4.5
9 & 10	*Saccharomyces cerevisiae* spoilage yeast with *Lactobacillus pentosus* LalOlive Crispy OL1 bacteria starter culture	4.5
11 & 12	*Lactobacillus pentosus* LalOlive Crispy OL1	4.5
13 & 14	*Lactobacillus pentosus* LalOlive Crispy OL1	3.5
15 & 16	*Lactobacillus pentosus* LalOlive Crispy with *Saccharomyces cerevisiae* spoilage yeast	3.5
17 & 18	*Saccharomyces cerevisiae* spoilage yeast	3.5

Unfortunately, again, none of these treatments showed decrease in spoilage by the pectinolytic yeast.

Activity 5: Measure pectinolytic activity in brine and in isolated yeasts.

Results: The pectinolytic activity in brine and olives was measured in all three sets of pilot fermentations. Pectinase activity was detectable in some cases just before excessive softening was detected, confirming that a simpler pectinase assay would be valuable for processors.

Activity 6: Measure oleuropein content of pilot fermented olives as an indicator of olive quality. Identify at least one starter culture that gives a final oleuropein content similar to that in traditionally processed Sicilian style olives.

Results: Because none of the treatments showed a decrease in spoilage, it was decided not to perform the measurement of oleuropein, which is a costly and time-consuming assay.

Activity 7: Perform at least one session of industry outreach, including presentation of research results, advice on sanitation and yeast inoculation, and writing a manual of guidelines for olive fermentations. Publish guidelines through the University of California, Davis (UC Davis) Olive Center website and distribute hard copies to California olive processors. Provide starter culture and assay training to processing facilities in California that handle Sicilian-style olives.

Results: The principal investigator, director from UC Davis Olive Center, and sanitation consultant from a privately held lab worked with three North California processors of Sicilian-style olives. Two weeks before the visit, the team sent out a questionnaire asking about food handling and sanitation practices. The processors each sent detailed answers. The sanitation consultant could point out several potential improvements in practices. A document of findings was drafted and shared with the olive processors. Starter cultures were not distributed to olive processors because none of the cultures tested were able to prevent excessive softening of olives.

Activity 8: Submit manuscripts to scientific journal for publications.

Results: The possibility of writing manuscripts for publication is being explored.

The project did not benefit any commodities other than olives.

All three major olive processors in Northern California were involved in this project, providing raw, freshly harvested olives for pilot fermentations. All three processors shared their standard operating procedures including olive sorting, fermentation, packaging and storage procedures, and sanitation practices. A detailed questionnaire was completed by all three processors describing their sanitation practices.

Goals and Outcomes Achieved

Goal 1: Develop simplified assays for the detection and control of pectinase activity in olive fermentations.
Target: develop a pectinase assay that does not utilize hazardous chemicals or expensive equipment
Progress: The published pectinase assay was used to evaluate pectinase activity in pilot-scale olive fermentations. This assay relies on staining of pectin in the agar plate using the dye Ruthenium Red, a hazardous chemical. The team was able to demonstrate that pectinase can be detected as early as eight days fermentation, before excessive softening is detected. This indicates that early detection of pectinase activity could become an important component of olive fermentation monitoring if suitable methods were developed for olive processors. Further development is needed for an improved protocol suitable for olive processors, but some advances were made:

- Several other pectin-based substrates were evaluated that are not laboratory grade, including pectin-based candies, prepared jellies, Sure-Gel and other brands of pectin available from the grocery store.
- The assay substituting Gram's Iodine for Ruthenium Red was tried. Gram's Iodine is less toxic, inexpensive and widely available, but unfortunately it did not result in suitable staining.
- Other detection strategies were explored rather than clearing in agar plates, including release of free glucuronic sugars.

Goal 2: Develop starter cultures to ensure consistently high-quality fermentations
Target: to develop at least one starter culture available for Sicilian-style olives.

Progress: The original project included pilot olive fermentations only in fall 2016. The team performed pilot fermentations in fall 2015, 2016 and 2017 thanks to some free visiting scientist labor and careful budget management. However, none of the pilot trials resulted in discovery of a starter culture that could mitigate the excessive softening caused by spoilage yeast *S. cerevisiae.*

Goal 3: Disseminate and explain microbial management recommendations for Sicilian-style fermented olives to table olive companies in California
Progress: As described above, a questionnaire about sanitation and food handling practices was sent to the three major Sicilian-style olive processors. Two facilities were visited to assess conditions and practices. A final draft of recommendations has been prepared and sent to the three processors.

Several potential yeast and bacteria were identified that had promising characteristics for use a starter cultures for Sicilian-style olives. These organisms and their properties are listed above.

Across three growing seasons, a total of 58 pilot fermentations were performed.

Working with an industry sanitation expert, and with input from three Sicilian-style olive processors, the team was able to identify some improvements in facility and process practices that could help prevent transfer of the spoilage organism within all three facilities.

Beneficiaries

The three major olive processors are the main beneficiaries of this work.
In addition, olive growers who provide the Sevillano Variety olives to these processors also benefitted indirectly from improved table olive quality.

An estimated 380 Sicilian-style olive growers, 10 processors, and 10 packers benefitted from the project. The direct beneficiaries of this project are the many olive producers and the three Sicilian-style olive processors. Identification of the organism responsible for excessive softening as a yeast leads to conclusions of potential strategies to mitigate contamination. Although a starter culture was not identified that could overcome the spoilage organism, several improvements were identified in sanitation practices that may decreased transfer of spoilage organisms within the facility. Processors have already implemented some improvements such as purchasing separate hoses for each tank, and cleaning the pump before circulating the next tank. Because this type of spoilage is sporadic rather than a consistent amount each year, the economic impact is hard to quantify but may be observed by processors over the coming years.

Lessons Learned

Positive: The olive processors were very engaged in this project, as excessive softening is a less frequent but very costly type of spoilage. They provided information on sanitation and fermentation practices, and also provided materials: olive, brine, buckets and screens for the pilot fermentations. A long history of positive interaction between UC Davis and the olive industry enabled this project.

Negative: The major difficulty of this project was the fact that olives are only harvested and fermented once per year, and are fermented for several months. Only one fermentation experiment could be done per year.

The openness of the three olive processors to sharing their fermentation practices, even though they were competitors of each other was welcomed.

In the second year of this project, an upper level undergraduate class on Food Fermentations was introduced in the Food Science and Technology department at UC Davis. In 2017 and 2018, the principal investigator gave guest lectures on olive fermentations in this class of 15 to 20 graduate and undergraduate students. Information gathered during this project was included in these lectures.

Students and staff learned the importance of having “backup plans”: as it became clear that none of the starter cultures identified would be able to prevent excessive spoilage. Increased emphasis was placed on developing recommendations for preventing transfer of the spoilage organism within the facility.

Additional Information

No additional information

USDA Project No.:	Project Title:	
22	Tools, Training and Opportunities for Organic Specialty Seed Producers	
Grant Recipient: Organic Seed Alliance	**Grant Agreement No.:** SCB15022	**Date Submitted:** December 2018
Recipient Contact: Jared Zystro	**Telephone:** (707) 502-9984	**Email:** jared@seedalliance.org

Project Summary

California has the largest organic specialty crop industry in the United States, representing more than 60 percent of the national acreage, a market value of more than $450 million in 2008, and an average 16 percent annual growth (United States Department of Agriculture, Economic Research Service). There is a large unmet demand from California's organic specialty crop industry for seed produced in and for organic farms. According to Organic Seed Alliance's (OSA) 2014 Organic Farmer Seed Survey, only 22 percent of organic specialty crop producers in California use 100 percent organic seed. The top three reasons given for not using organic seed highlight the gap in quantity and diversity of seed available. Seventy-nine percent stated that varieties they need were not available organically, 37 percent stated that available seed lacked key genetic traits, and 36 percent stated that insufficient quantities were available for the varieties they used. California is the leading vegetable seed producing state and organic seed producers have the potential to help meet organic specialty crop producers' seed needs. However, producing high-quality seed requires specialized skills, tools, and market access.

In February 2015, OSA hosted the first California Organic Seed Summit as an intensive strategic planning session for California organic specialty seed producers and distributors with the goal of identifying work that will help organic specialty crop seed producers succeed. Summit participants identified the key objectives of 1) providing instruction in seed quality and seed business; 2) Increasing availability of specialized tools; 3) Increasing market demand; and 4) Increasing information sharing between producers as necessary to increase the quality, quantity, and diversity of organic specialty seed available in California.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

A. Project start

In November of 2015, all project partners were convened for a project on-boarding process where the project tasks and timeline was outlined, each partner's responsibility was detailed, and the procedures for ownership and communication were conveyed.

B. Develop application process and supply stipends for producers to attend the University of California, Davis (UC Davis) three-day Seed Biology, Production and Quality course and the five-day Seed Business 101 – Horticulture course.

An application process was developed and distributed through OSA's California specialty seed email lists. Applicants were asked to commit to sharing content from the courses within their hubs. In 2016, three producers attended the seed business course and three attended the seed production course. In 2017, seven

producers attended the seed business course. In 2018, two producers attended the seed production course. Course attendees completed a course evaluation and shared information from the courses at regional workshops and at the annual California seed summits.

Written feedback was collected from the six participants and the overall tone was very positive. Participants stated that the information was valuable and it that would help to operate more efficiently. In response to the question, what did participants find most valuable about the course, respondents stated that the information about inventory management, the networking with seed industry peers and the resource binder that was provided during the course were the most valuable.

C. Promote and hold seed production and business workshop track within the California Organic Seed Summit led by experienced organic specialty crop producers.

The 2016, 2017, and 2018 California Organic Seed Summits were promoted through invitations by OSA to experienced seed producers, seed sellers, and allies. In each of the annual California Organic Seed Summits, experienced seed producers, seed company representatives, and other experts presented information on specialty seed production, marketing and business. The 2016 summit had 33 attendees, the 2017 summit had 34 attendees, and the 2018 summit had 36 attendees.

D. Promote and host field days held on organic specialty seed farms in each of the five regions (Northeast, Northwest, Sierra/Sacramento, Bar Area, and South Coast), highlighting production techniques, variety choices, and equipment. Conduct participant surveys.

Regional field days were promoted through each hub's network, through press releases to local media, and through OSA and partnering organizations' contact lists. Ten field days were held in total throughout the state during the project period, with a total of 224 attendees.

E. Promote and deliver one-day Organic Seed Production and Variety Maintenance courses in each region, reaching producers who may not attend the longer courses held in Davis, and conduct participant surveys.

Organic Seed Production and Variety Maintenance courses were promoted through each hub's network, through press releases to local media, and through OSA and partnering organizations' contact lists. Ten workshops were held in total throughout the state during the project period, with a total of 202 attendees.

F. Identify and purchase key tools that will benefit multiple producers in each region and allow them to increase their production. Each regional coordinator will manage the tool sharing program in such a way to ensure that as many users have access to the tools when they need them and that the tools are maintained and will manage a tool record system.

Specialty seed cleaning and processing tools were purchased based on the specific needs of each hub. These included air-screen cleaners, air column separators, threshers, winnowers, screens, a wet seed cleaning "sluice", and custom-build seed inventory management software. Tools were shared in locations central to producers in each hub and advertised via the hub networks. Producers kept logs of the seeds cleaned with the tools.

G. Develop a wholesale producer database that will allow distributors and large purchasers of organic specialty seed to directly purchase seed or contract for seed production from California organic specialty seed producers.

Based on feedback from California specialty seed crop producers, an online producer database was developed to promote California organic specialty seed producers to seed companies and wholesale purchasers. Its user-friendly interface allows buyers to search based on location, scale of production, crop type, organic certification and other criteria (Directory here: https://seedalliance.org/directory/).

H. Develop and distribute marketing materials that promote the value of California organic specialty seed to potential purchasers.

OSA developed and printed a California organic specialty seed grower's directory. The physical copy of the directory also promotes the online database profile tool and will be used to help direct traffic to that database. The print directory was shared with seed companies and wholesale and retail seed buyers and farmers at the national Organic Seed Grower's Conference, February 14-16, 2018, at the Grow Riverside farm conference in Riverside, California on April 4, 2018 and at the Seed Production workshop in Spring Valley, California on April 7, 2018. The overall reception of the printed directory has been positive.

I. Create and advertise producer and distributor marketing networking opportunities at the annual California Organic Seed Summit.

The 2016, 2017 and 2018 California Organic Seed Summit programs included a "seed showcase" - a dedicated networking session, which was popular. Contract managers from prominent seed company attended in 2017 and 2018 and fielded questions from participants about the contracting process, which participants found very valuable. The retreat setting provided continuous opportunities for informal networking throughout the weekend, and participants were observed exchanging information with producers and buyers with whom they intended to establish new contracts.

J. Increase the awareness of the importance of regionally produced organic specialty seed throughout the production chain by promoting and hosting "Seed to Eater" roundtable meetings with organic specialty seed producers, farmers, wholesalers, retailers, and chefs at the Ecological Farming Conference.

The "Seed to Eaters" symposium was held January 25, 2017 at the EcoFarm Conference in Pacific Grove. Attendees included 29 seed producers, plant breeders, chefs, wholesale produce distributors and farmers. This symposium was a unique event where a broad range of sectors in the food system were represented and enlisted to participate in supporting the specialty seed market. The agenda began with successful examples of relationships between breeders or seed producers and distributors, chefs, or seed companies. Following this, a facilitated discussion focused on developing plans to help members of the food system benefit from access to increased seed diversity, ending with taste tests of novel varieties.

K. Develop a flexible database that will allow producers to share records on crop yields, seed inventory, pricing, and product development research such as trial and breeding results.

To support crop yield and inventory recordkeeping, OSA contracted with a database developer to create a custom seed inventory database (http://seedinventorytool.seedalliance.org/). During its final beta testing, multiple California specialty seed crop producers were already using it to track their seed inventory.

OSA has identified efforts already underway to research and produce a database to track breeding and trial results, and are supporting this effort (http://www.seedlinked.com/).

L. Advertise and host information sharing roundtables at the California Organic Seed Summit.

The roundtables have been determined to be a valuable part of the Organic Seed Summit format. Feedback from the 2017 Organic Seed Summit attendees confirmed that roundtable information sharing was a valuable part of the Summit. Time for information sharing roundtable discussions was factored into the 2018 Organic Seed Summit agenda and was advertised as part of the program with the registration information.

Specialty crops were only included in all project-related education, trials, and marketing efforts. The outreach to target specialty crop growers was additionally focused. Non-specialty crops were not included in any project education or research activities.

OSA staff and contracted employees managed the overall project and ensured that all components of the project were executed. OSA developed the application process for the Davis courses; delivered the Organic Seed Production workshops and coordinated the field days; organized, moderated and delivered seed production, business and marketing content at the Organic Seed Summits; coordinated the purchase and deployment of seed cleaning tools; created and distributed the printed California seed growers directory; managed the development of the online seed producers database; and co-organized and co-hosted the Seed to Eaters symposium.

The Ecological Farming Association (EFA) co-organized and co-hosted the Seed to Eaters symposium as part of the 2017 EcoFarm conference. EFA staff organized the agenda and symposium logistics and provided the facilities. In addition, EFA provided outreach and communications support for regional hub activities through its mailing list and social media presence.

UC Davis organized the course and delivered instruction to attendees of the Seed Business and Seed Production courses. In addition, UC Davis provided input on the Organic Seed Production intensive content and provided training and variety development updates to attendees of the 2016, 2017, and 2018 Seed Summits.

Sierra Seed Cooperative assisted in the development of the 2016 seed summit and Sierra region field days.

Redwood Seed Company managed the Northeast regional seed hub, conducting outreach to regional specialty seed producers, identifying the seed cleaning tools needed and coordinating the use of those tools, and organizing regional workshops and field days. In addition, Redwood Seed Company assisted in the planning of the 2016 Seed Summit.

Goals and Outcomes Achieved

Activities completed to support Goal 1 -- more California farmers will be growing and selling organic specialty crop seed commercially, and they will be doing so efficiently and profitably:

- Delivered three California Organic Seed Summits, with in-depth training in seed production and seed business, farmer-to-farmer information sharing, networking and market building, and community planning.
- Delivered 11 specialty seed production workshops and 11 specialty seed production field days throughout California.
- Trained specialty seed producers and specialty seed business owners at two, three-day Seed Biology, Production and Quality courses and two five-day Seed Business 101 – Horticulture courses.
- Purchased and deployed 18 pieces of specialty seed cleaning and processing equipment at regional hubs throughout California.
- Marketed specialty seed through the printed California seed grower's directory, the seed showcases, the "Seed to Eater" symposium, and the online seed producer database.

Activities completed to support Goal 2 -- California organic farmers will have greater access to regionally grown and adapted organic specialty crop seed:

- In addition to the activities list above under Goal 1, which also contribute to farmers' access to regionally grown and adapted organic specialty crop seed, the follow activities focus on variety development support supported Goal 2:
- Variety development training during the 11 seed production workshops
- Variety development training and state-wide variety trial result information sharing during the three California Organic Seed Summits.
- Farmer breeder participatory breeding planning with UC Davis during the three California Organic Seed Summits.

Comparison of actual accomplishments with the goals established:
Goal 1: More California farmers will be growing and selling organic specialty crop seed commercially, and they will be doing so efficiently and profitably through improved production skills, the shared use of seed production tools, and increased access to markets.

According to questionnaires at educational events, email follow-ups, participation in the annual seed summits, tracking seed tools usage, records from the shared production record database, and listings in the organic specialty seed producer's database, more farmers are successfully growing and selling organic seed.

Goal 2: California organic farmers will have greater access to regionally grown and adapted organic specialty crop seed.

According to questionnaires at each educational event, email follow-ups after the events, records from the shared production record database, and listings in the organic specialty seed producer's database, more adapted organic seed varieties are being grown and sold in California.

Completion of achieving outcomes:

Goal 1 target: By the end of the grant period, 20 or more farmers will be entering the seed trade by growing and selling organic specialty crop seed.
Benchmark: According to the National Organic Program (NOP), there are currently approximately 50 California organic specialty seed producers.
Outcome: Currently, 69 organic specialty seed producers are listed in NOP's database.

Goal 2 target: By the end of the grant period, California organic specialty seed producers will be marketing 20 or more varieties of regionally adapted organic specialty crop seed.
Benchmark: There are no popular sources of commercial quantities of regionally grown and adapted organic specialty crop seed, and there are few varieties listed as "adapted for organic California farms."
Outcome: Currently, 95 regionally adapted varieties are available through California organic specialty crop producers.

This project provided the tools and support for California producers to efficiently and profitably produce and distribute organic specialty seed, providing California organic farmers with greater access to regionally adapted specialty crop seed. It did this by training over 250 current and aspiring specialty seed producers through workshops, short courses, field days, and summits; by deploying over 20 seed cleaning tools through regional hubs; and by creating marketing channels such as the online and printed seed producer's directories and Seed to Eaters event; and by building a peer-to-peer network through the seed summits, California organic seed listserv and regional hubs. This has resulted in new California seed producers, including 69 organic specialty seed producers listed in the NOP's database. It has also resulted in new regionally adapted varieties including 95 varieties listed by survey respondents.

Beneficiaries

Beneficiaries included California organic specialty seed producers, California organic special seed sellers, and organic and sustainable specialty crop producers nationwide.

Over 250 current and aspiring California specialty seed producers benefited from this project. According to the interviews and questionnaires distributed to participants, of those who responded, 60 percent indicated that they were currently producing organic specialty crop seed and, of those respondents, approximately 25 percent began production during the project timeframe. Additionally, the NOP organic producer database showed an increase of 19 organic seed producers between when the project started and when it was completed.

Lessons Learned

While the hub model was successful in terms of building regional networks, one of the lessons learned was about the challenges that exist when relying on key regional seed producers for project activities. Although these regional producers had both the motivation and some of the regional network already in place to bolster their success, the fact that their relationship to this project was so tightly tied to their primary enterprise carried risks. In particular, if their business in seed production or seed sales changed they had less incentive to work on project activities. Fortunately for this project, thanks in part to the regional strong networks, identifying and training new hub leaders was successful when necessary.

Among the positive unexpected outcomes from this project was the strengths and benefits that emerge solely from creating a network of like-minded producers, vendors, and service providers. The project was designed

to encourage network building via the regional seed hub model and the in-person and virtual networking happening at the seed summits, the California seed growers' listserv and other events. This led to new projects developing among network members, including the Seedlinked start-up (http://www.seedlinked.com/) and the Davis Student Collaborative Organic Plant Breeding Education project.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
23	Specialty Crop Internship Listing Website	
Grant Recipient: CalAgJobs	**Grant Agreement No.:** SCB15023	**Date Submitted:** December 2018
Recipient Contact: Shannon Douglass	**Telephone:** (530) 680-4545	**Email:** shannon@calagjobs.com

Project Summary

With a shortage of qualified professionals to support specialty crop production and decreasing student enrollment in related fields, it is more important than ever to showcase the specialty crop internship opportunities to draw more people into this career path. This project was developed to create a comprehensive listing of California specialty crop internships, free for industry to use and free for students to access. This would be a benefit to specialty crop producers who could more easily advertise for and recruit interns, and a benefit for the industry as a whole as it would be better able to attract people into internships and considering long term careers in specialty crops.

Currently, there are approximately 4.5 jobs for every graduate in crop and plant science. Forty-five percent of all career opportunities in agriculture are focused on crops and plants, yet it remains only the fifth most popular college major. As a result, there is a very tight pool of potential employees for the specialty crop industry. While the demand for specialty crop careers has grown, students are not realizing the reality of where the demand for careers exists within agriculture. This project sought to shift that understanding by providing a comprehensive listing showcasing the abundance of opportunity with specialty crop internships in California. This project provided a free resource that specialty crop producers can use to advertise their internships, and helped the interns fill short-term labor needs. The purpose of this project was to create a central database to advertise specialty crop related internships in California to get more students to consider these career pathways in the long term. There is a serious shortage of qualified crop science professionals, roles vital to specialty crop producers--big and small. This project sought to lessen that shortage by recruiting more students into these pathways by way of internships.

With 4.5 jobs for every crop science grad in California and with a majority of the crop production in California being specialty crops, more talent is needed in this industry if the next generation of growers will be successful.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The project staff created a section of the website to list specialty crop internships for free and allow people to list the internships in a self-service option. The project staff promoted the internship listing to industry at a variety of targeted events over the last three years, with attendances at some events exceeding 14,000 people. The project staff also promoted these internships to students at college career fairs and to their teachers at specific ag teacher events. The project staff promoted the internships to industry in publications, by mail, via social media, and even using a billboard in the central valley.

The project staff hired a Web Developer and Graphic Designer contractor who added an internship page to the existing website with additional search functions. The page was added to the website with the ability to search and classify internships by type. One of the most complicated tasks was making the internship postings be self-service so that it did not require additional staff time. The project staff continuously tested the site functionality to improve features. The project staff received substantial feedback which led to fixing various site bugs and make the process smoother for users.

Marketing pieces were created that would target industry members. The language was specific as to encourage employers and Human Resources departments to use this service to advertise their internships. The marketing pieces directed to students featured their peers. The project staff worked to select students from diverse backgrounds to better represent diversity so that students had a sense of seeing themselves in the materials. There are very limited stock images of specialty crops and especially of diverse populations with cover crops. This would be a great area to support in the future so that there are more stock photos available for this sort of use.

The project staff conducted visits to the colleges of agriculture and key community college events; as well as, industry events and trade shows to promote the internship page to students. The project staff advertised free internships in California agriculture publications (see goals and outcome section for details).

The project staff purchased a mailing list of wine grape attendees that project staff found to be very cost effective and did a massive postcard mailing of approximately 10,000 postcards. This proved fruitful and resulted in some of the first postings.

The project staff spent approximately 50 dollars per month during the project duration and targeted ads to college students interested in agriculture. This was an interesting process as the social media advertising rules changed continuously along the project course. The project staff devoted many hours to learning what search terms and types of ads worked best. As ads became more important on mobile devices, project staff worked to shorten the ad text and use more images. The project staff also worked to spend the budget making shorter ads with a higher daily spend. This resulted in more engagement than longer ads with smaller daily budget. The ads directed students to the internship posting page or to sign up for the specialty crop internship newsletter.

Specialty crops were the only crops featured in the promotional pieces and sorted internships.
CalAgJobs worked closely with the California Community Colleges, the California State University Chico and Fresno, University of California Davis, and the California Polytechnic State University San Luis Obispo and Pomona to maximize the student reach. The Community College system was especially helpful in providing access to their instructors during their annual teacher meetings.

Goals and Outcomes Achieved

Activities completed included the following:
Industry events:
World Ag Expo – The project staff had a booth for three years at the largest farm show in the world to promote the ability to advertise internships for free.

Colusa Farm Show – A booth was here for two years to promote the free internships but dropped the booth in year three due to lower than expected event attendance.

Unified Wine and Grape Symposium – A booth was here for two years promoting the ability of viticulturists to use the free internship postings. This event had nearly 15,000 people attend.

Sustainable Ag Expo – The project staff attended this event to improve the outreach to the central coast specialty crop producers. This event had several hundred people attending but attracted growers who do not always attend the valley events.

Almond Conference – The project staff exhibited at the conference for one year to promote the internship posting website. This provided outreach to over 2,500 specialty crop growers in California.

Student Outreach Events:
State FFA Conference – The project staff attended this event in years 2 and 3. This event had over 5,000 students who attend the event plus their teachers. The project staff talked to students about internships and to the instructors about promoting them.

California Ag Teachers Association Conference – This annual event is the largest gather of agriculture instructors in California. The project staff had a booth at this event and provided resources to teachers including posters.

Numerous Career Shows in California – The project staff had a promotional booth at a wide variety of community college and four-year college career shows across California to promote specialty crop internships. This included California State University, Chico, Fresno, San Luis Obispo, Pomona as well as Modesto Junior College.

Mid-Winter Institute for Community College teachers – The project staff attended this event all three years as the primary outreach to the agriculture instructors of California's community colleges. The project staff gave talks and provided handouts, brochures and posters to promote internships to the students.

Advertising:
The project staff conducted numerous promotional mailings to specialty crop growers and associated specialty crop businesses to encourage them to use the website to advertise their internship opportunities.
The project staff promoted the free internship postings in the California edition of Western Farm Press for three issues with large advertisements for three months in year one of the project.

Ag Source – The project staff did several advertisements with Ag Source which has a strong audience in the central valley.

Ag Alert – The project staff conducted a total of five advertisements over the course of the project promoting the opportunity to post and promote internships for free.

AgNet West Radio – In the final few months of the project, project staff began a partnership with AgNet West radio to promote the internships on air during their ag news segments.

Central California Billboard – In February 2018, project staff advertised on a billboard along Highway 99 in California, to promote the free internship opportunities. The location was targeted to reach the thousands of visitors attending the World Ag Expo. Social Media paid this advertising.

While it is very difficult to measure the long-term impacts of students choosing careers, project staff are confident that specialty crop careers have received more attention by teachers and students as a result of this project.

This project started with no benchmark and no central place for internships in California agriculture, now there is a central place as a resource to growers and the entire specialty crop industry. The project staff achieved the goal of page views with over 10,000 views of internships on the website. The project staff missed the goal of 200 internships posted, with only 150 posted. This was challenging to quantify because many of the individual postings were actually for multiple positions with the same descriptions.

Beneficiaries

The project staff were very pleased to see specialty crop growers and businesses of all sizes across California benefit. From large corporations to individual owners, all could utilize the same free service. The long-term goal is that more students will be attracted into specialty crop internships and that they will seek these as their careers long term, providing benefit to many other specialty crop producers. One hundred and fifty students who were interns benefitted from this project as did the 107 individual organizations and companies who advertised internships.

Lessons Learned

One of the biggest challenges was getting growers and companies to use the self-service option for uploading their internship job descriptions. The project staff planned on self-service as a way to keep the labor very light and make it easier for the project to continue in perpetuity. The second major challenge was growers or Human Resources specialists in California not understanding the meaning of specialty crops. Because specialty crops in California are major crops, people assumed grapes and nuts didn't count. This was problematic in advertising having limited space to try and list all the included crops. The final challenge was that during the course of the grant, several of the agriculture colleges made their career fairs into income generating events and substantially raised prices. Most colleges worked with project staff, but one major institution did not and project staff were not able to get on that campus to promote internships to those students.
An internship newsletter for students was added to the project with no additional cost; when new internships would post, project staff sent an email thread in hopes of getting more students to apply. The project staff finished the project with over 500 students having been a part of that list. This was a great additional tool that project staff believe helped get the intern host more applicants.

Having people identify as specialty crops was a challenge that could be faced by other grants in the future. The project staff were not sure what could have been effective in overcoming this problem. The project staff believed that using the phrase "specialty crops" alone and not providing further description was a detriment in the marketing materials. It should have been broader to attract more growers. Many thought they weren't specialty crops or did not know the full list of specialty crops and thus, did not engage in the project. Toward the end of the project, project staff included more information with the phrase "specialty crop" and saw a final surge in use. Perhaps if this was done sooner, project staff would have hit the 200-internship target goal.

Additional Information

The project website: www.calagjobs.com

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
24	Grower Education for Farm Water Quality Practices	
Grant Recipient: Sonoma County Agricultural Commissioner	**Grant Agreement No.:** SCB15024	**Date Submitted:** December 2018
Recipient Contact: Shelley Janek	**Telephone:** (707) 565-2371	**Email:** shelley.janek@sonoma-county.org

Project Summary

The North Coast and San Francisco Bay Regional Water Quality Control Boards (Waterboards, Region1 and Region 2 respectively) have identified pollutants from vineyard and orchard stormwater runoff as detrimental to stream habitats. These Waterboards have developed or continue to develop new regulations for vineyards and orchards to reduce their environmental impacts. These new regulations require vineyard and orchard operators (operators) to develop and follow Farm Water Quality Plans (Farm Plans), which identify contributing sources of sediment, nutrient, and pesticide pollution, and describe actions to eliminate or prevent pollution sources from impacting waterways. The Farm Plan regulations require operators to address sources of erosion on their operations or face possible sanctions from the Waterboards.

Many smaller operators are unfamiliar with the principles of erosion and water pollution prevention required to develop and implement these plans. As a result, there is a clear need to provide information to operators regarding farm and drainage infrastructure and overall management to improve water quality and the operators' abilities to comply with the new regulations. The overall objective of this project was to educate operators about practical methods for minimizing pollution runoff into streams, thereby increasing their abilities to satisfy the new regulations. To achieve this objective, the project included two primary components. First, the project developed an instructional guide that provided narrative explanations and diagrams of methods operators can adopt to prevent water pollution within the context of the new regulations. Second, the project included a series of outreach efforts to disseminate erosion control information and technical guidance about proper implementation of erosion control and stormwater management practices. By providing this instructional guide and outreach to operators, the project increased the awareness and competencies of operators to adopt and implement new practices in a manner that mitigates or prevents stormwater pollution from reaching streams and wetlands as mandated by the Waterboards.

It is anticipated that additional California waterboards with significant vineyard and orchard economies, such as the Central Coast, will be implementing similar stormwater regulations in coming years. Many of these regions do not have local regulations for the prevention of erosion from vineyard and orchard operations. Development of the Land Steward's Guide to Vineyard and Orchard Erosion Control (Guide) has increased the likelihood that the operators will utilize principles from the Guide to adopt and implement new practices in a manner that mitigates or prevents stormwater pollution from impacting waterways. This project supports both the Waterboard mandates and larger environmental protection processes.

The project's importance and timeliness were identified and driven by upcoming Waterboard regulations and the Sonoma County Agricultural Departments (Ag Department) commitment to support agriculture in Sonoma County. The Ag Department, through discussions with agencies and stakeholders, developed a plan to assist operators by providing the following: 1) erosion control information and technical assistance in meeting upcoming regulatory requirements, 2) educational materials to support land stewardship principles

and local ordinance requirements, and 3) support for the economic viability of the agricultural industry in Sonoma County and beyond.

1) The Region 2 Waterboard has adopted the General Waste Discharge Requirements for Vineyard Properties in the Napa River and Sonoma Creek Watersheds. This regulation was adopted in July 2017 with an enrollment deadline of July 2018. Farm Plans are required to be completed and verified by July 2020. The new Guide is a timely resource to assist landowners in developing and implementing their Farm Plans in compliance with these regulation timelines.

   The Region 1 Waste Discharge General Permit is currently being drafted and will carry similar watershed protections, necessitating additional demand for erosion control and sediment management information. The Ag Department is now prepared to provide copies of the Guide and technical assistance for Region 1 enrollees.

2) Within Sonoma County, the Vineyard and Orchard Development and Agricultural Grading and Drainage ordinance (Vesco) provides guidance and recommendations for erosion and sediment control through the Vesco permit application/review process. Regulation of vineyard and orchard operations however, is not widespread. As a result, providing this informational Guide is a valuable service to operators, governmental organizations and non-profits outside of Sonoma County. Individuals may access and learn directly from these materials, and technical assistance providers may use this material developed by Sonoma County to inform and guide their own workshops and/or regulations. While the Guide focuses primarily on compliance with the Waterboard regulations, the core content around practical methods for vineyard and orchard environmental stewardship will be relevant for vineyard and orchard operators in general.

3) Beyond these environmental benefits, the project has helped to maintain the economic competitiveness of operators on several levels:
   a. Discharges to streams or waterways can result in financial sanctions for failing to comply with the new regulations. Proactive use of the Guide can assist operators in avoiding costly fines.
   b. Absence or negligent installation of erosion control measures often results in expensive fixes. The Guide's recommended Best Management Practices (BMP) and installation instructions provides an educational opportunity for field crews and can circumvent costly mistakes.
   c. Erosion and pollution control is a critical aspect of the various sustainability certification programs, an important wine marketing tool and a premium grape marketplace. The Guide provides the tools required to produce an Erosion Control Plan, a key element in any certification process.

Completion of the project prior to Waterboard regulations has provided vineyard and orchard operators with important tools they will need to meet regulations, while also assisting operators to create more sustainable operations, and compete more effectively in a changing agricultural environment.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The following tasks were accomplished by Ag Department staff during the grant period:

Development of The Land Steward's Guide to Vineyard and Orchard Erosion Control:

- Research into all aspects of the erosion process and how to prevent or mitigate the impacts of erosion consumed significant hours of staff time. The need for erosion control, what causes erosion, how to identify true causes of erosion and what to do about the resulting impacts were the broad topics of research which informed the content of the Guide. The Guide's contents include:
    - Introduction
    - Chapter 1: General Principles of Erosion Control
    - Chapter 2: Managing Surface Erosion from Cultivated Areas
    - Chapter 3: Managing Sediment Delivery from Roads
    - Chapter 4: Managing Stormwater Runoff
    - Chapter 5: Managing Gullies and Shallow Landslides
    - Chapter 6: Pollutant Control – Pesticides
    - Chapter 7: Pollutant Control – Managing Nutrients
    - Chapter 8: Winterization and Sustainable Maintenance
    - Glossary
    - Additional Resources
    - References
    - Image Credits
    - Appendices 1-5
- Development of the actual erosion control Appendices: BMPs likewise consumed significant portions of time. Each appendix corresponds to its parent chapter with BMPs relevant to the chapter subject matter. Defining each BMP, identifying design considerations or constraints, providing installation guidelines, and outlining maintenance requirements produced five appendices and 25 different BMPs in shovel-ready format for production crew field use.
- To ensure accurate, current, and usable methods, staff consulted with RCDs, multiple Waterboards, vineyard management companies, monitoring entities, online sources and other partners and incorporated this information into the Guide to produce a resource which provides a one-stop reference Guide for vineyard and orchard operators. Over 20 outside contacts provided input into the draft Guide.
- Editing, formatting and internal review were completed prior to sending out for peer review to project partners. Peer review was accomplished by five agencies chosen for their expertise and interest in erosion control.
- Printing and Spanish language translation produced 400 English language and 250 Spanish language copies of the Guide.
- Website content and layout were discussed internally with the intention of developing a stand-alone page for the Land Stewardship Division. However, costs prevented development of a stand-alone page. Project materials were instead added to the Ag Department webpage in both English and Spanish. A link to both copies is provided at the end of this report.
- Outreach materials consisted entirely of the Guide as a handout. The comprehensive nature of the Guide's content precluded adding any additional materials.

Education and Outreach:

- The Ag Department partnered with The Farm Bureau, the Sonoma County Winegrape Commission, the Region 2 Waterboard and the Sonoma Resource Conservation District on pre-scheduled

workshops and events. Seven outreach events were held with partners on December 7, 2017, February 28, March 21, March 23, May 3, May 9 and June 1 of 2018. A total of 635 growers attended.

- Communication outreach to the growers was accomplished through Ag Department pesticide use email list, Farm Bureau membership, Region 2 Waterboard outreach, and the Wine Grape Commission membership.
- During outreach events, the Ag Department provided an introduction to the Guide via video, discussion of Guide chapters and relevance to erosion control management, discussion of the Appendices and proper use of BMPs, and management of surveys.

Deliverables:

- Research into appropriate survey formats was conducted prior to development of the Operator's Survey. A survey was designed to track participant's knowledge levels on Erosion Source Assessment & Prevention, Erosion Control Practices, Storm Water Runoff Management, Pesticide Management, Nutrient Management, Road Maintenance, Drainage Infrastructure Maintenance, and Maintenance of Installed Erosion Control Measures. Survey results were tabulated into the Deliverables spreadsheet for project success tracking.

  A pre- and post-workshop survey was not a logistical option for this project as surveys are generally not well received by attendees. It can be difficult to achieve a 20 percent success rate for one survey. Multiple surveys generally do not fare as well. For survey purposes, the assumption was made that attendees were average operators and would mirror the responses received from the baseline survey. Knowledge increases were determined by increases in intermediate and professional levels reported per total responses.

  Following outreach events, the survey results were tabulated and any comments recorded for future events.

- Website hits and downloads: Due to staffing changes and wildfires in Sonoma County, the development and printing of the Guide and proposed outreach efforts were delayed until 2018. This significantly affected the time available to achieve the website hits and downloads targets. While the project did not achieve the target numbers, staff believe that website hits and downloads over time will reach the goals predicted as more outreach occurs.

The following agencies/organizations were instrumental in project success:

1) North Coast Regional Water Quality Control Board: Through collaborative efforts with the Ag Department, the Waterboard provided valuable insight into the regulatory framework for the Waste Discharge Waivers which informed the Guide's content. The Guide was designed to provide the information necessary to assist operators in crafting Farm Plans required for the Waivers. The Waterboard provided Guide review and oversight for alignment with upcoming regulations. The Waterboard also partnered with the Ag Department on outreach efforts during Region 2 Waiver program rollout which enabled greater distribution of the Guide and greater education of operators.
2) Sonoma Resource Conservation District (RCD): Served as contributor of material for the Guide, reviewer of final draft, and participant in outreach efforts. The Ag Department also attended RCD events to

distribute Guides and provide technical assistance as needed. The RCD has continued to distribute copies of the Guide at scheduled RCD events.

3) RCDs of Goldridge, Napa County, Monterey County, Marin, and Upper Salinas/Las Tablas: Contributed prior erosion control publication materials incorporated into the Guide.
4) University of California Cooperative Extension served as contributor and reviewer of the Guide, particularly in Integrated Pest Management, pesticide application and nutrient management sections of the Guide.
5) LACO Associates: Provided valuable material for gullies and landslides and review of engineered erosion control measures.
6) Russian Riverkeeper: Contributed materials, BMP monitoring observations and final review of the Guide.
7) Sonoma County Farm Bureau: Provided partnership, outreach efforts and venues for Ag Department distribution of the Guide and educational opportunities for operators.
8) Sonoma County Winegrape Commission: Contributed outreach efforts and events at Shone Farm for Ag Department distribution of the Guide and educational opportunities for operators.

Goals and Outcomes Achieved

The activities completed to meet outcomes include:

- Development of Land Steward's Guide: Research of erosion control and management for the Guide; consultation with agencies and stakeholders to align the Guide with regulatory requirements; peer review; editing, formatting and printing of the Guide; Spanish language translation of the Guide; posting of both English and Spanish editions to the website.
- Outreach and Education: collaboration with partners on outreach efforts; contact with growers through Ag Department email lists and partners membership lists; development of an introductory video for use in outreach; participation in a total of seven outreach efforts;
- Baseline data of operators current knowledge levels, pre-outreach event: Development of survey for tracking of knowledge levels; distribution, collection and compilation of surveys to create the Baseline/Benchmark data for project success measurement.
- Thirty percent of attendees will complete surveys: Development of deliverables spreadsheet to track all Measurable Outcomes; encouraged survey completion at all outreach events; tracked attendees, surveys, knowledge levels, submitted comments/suggestions, and website hits.
- Ninety percent of attendees will show increased knowledge levels: Instructed attendees to score knowledge levels on surveys; track project success after each outreach effort; incorporate any suggested comments/changes.
- Five thousand website hits and 1,000 website downloads: Development of website tracking mechanism. Utilized partnerships to reach growers via emails and publications, establishing the Guide's availability on the Ag Department website.

No long-term outcome measures were proposed for this project however, the potential to disseminate developed material outside of Sonoma County was considered both highly probable and of great value. The Ag Department intends to continue distribution of the Guide at future events as well as providing copies of the Guide to project partners for use in their outreach efforts. The Ag Department online versions of the Guide are available for review and download both nationally and internationally.

The Expected Measurable Outcomes include:

- Target: Five outreach events with a total of 300 attendees: A total of seven outreach efforts were completed. As previously stated, the Ag Department partnered with several agencies/organizations in anticipation of greater attendance numbers. The final attendance count for all events totaled 635 attendees.
- Target: Baseline data of operators' current knowledge levels, pre-outreach event: The Ag Department held a Grower's Workshop in December 2017 attended by 300 growers. Surveys were distributed, collected and compiled to create the Baseline/Benchmark data from which project success was measured.
- Target: 30 percent of attendees will complete surveys: For all events, 127 surveys were completed: 66 baseline surveys and 61 post-baseline surveys. Throughout the course of all events, a 20 percent return on surveys was consistently achieved.
- Participant comments/suggestions/improvements incorporated: The distributed surveys contained a section for comments/suggestions. Few respondents provided comments and those received were requests for additional workshops. No suggested improvements were noted.
- Target: 90 percent of attendees will show increased knowledge levels: The method the Ag Department used to analyze survey results indicated that nearly 100 percent of attendees increased knowledge in at least one of the eight categories surveyed.
- Target: 5,000 website hits and 1,000 website downloads: The Ag Department instituted a webpage counter after publication of the Guide in early 2018. The County Information Services Department was not able to track individual downloads without significantly modifying the Ag Department website, adding a six to eight week delay in tracking. Therefore, the Ag Department was able to track website hits only. Due to the delayed nature of the project, website hit tracking began in December 2017 and ran through the end of November 2018. A total of only 127 hits on the Guide were recorded. The Ag Department made every effort to increase awareness of the Guide availability, through Farm Bureau newsletters and e-blasts through partners, but website traffic did not significantly improve in the short time span available.

On December 7, 2017 the Ag Department held its annual Grower's Workshop. This is a mandatory gathering related to pesticide usage and covers regulations, informational exchange, and other Ag Department presentations related to agriculture in general. Over 300 growers attended this meeting, making this the ideal situation for collecting baseline data for the project. The Ag Department displayed the introductory video and provided a short presentation on the Guide's contents. Surveys were distributed in the registration packet each grower received on sign in. Several reminders to complete surveys were mentioned during the course of the day and a total of 66 surveys were returned at the conclusion of the event. Those results were tabulated by assigning a point for each response in eight categories. After compilation, the baseline data was as follows:

- Basic Knowledge – 33 percent
- Intermediate Knowledge – 52 percent
- Advanced/Professional Knowledge – 15 percent

Six post-baseline outreach events were held on February 28, March 21, March 23, May 3, May 9, and June 1 of 2018. Attendees were instructed to rate their increase in knowledge on eight subjects. Following these events, compilation of survey data returned the following averaged results:

- Basic Knowledge – 12 percent
- Intermediate Knowledge – 65 percent
- Advanced/Professional Knowledge – 23 percent

This represents the following percentage changes upon project completion:

- Basic Knowledge – Decreased 21 percent
- Intermediate Knowledge – Increased 13 percent
- Advanced/Professional Knowledge – Increased 8 percent

The results indicate more increases in intermediate and advanced knowledge after outreach and a decrease in basic knowledge levels. Based on these results, the targets set for this project were achieved.

Beneficiaries

The targeted beneficiaries of this project were vineyard and orchard operators affected by stormwater regulations being adopted by the Waterboards. There are approximately 2,000 vineyard and orchard operators in Sonoma County and 5,900 of these growers throughout the state. The project proposed to benefit the growers in three core ways: 1) Through outreach efforts, this project planned to serve at least 300 vineyard and orchard operators; 2) By making the instructional Guide freely available online, the 5,900 growers throughout the state will have access to valuable guidance for implementing stormwater pollution prevention methods; and 3) By posting the Guide online, other local government and nonprofit organizations will have the opportunity to easily and cost-effectively host their own workshops for local vineyard and orchard operators. Education benefits accrue because design and implementation of erosion controls can be expensive and time-consuming, and improper installation can result in additional costs including reinstallation, habitat restoration, and agency penalties. Through proper design and construction specifications, a single operator could save tens of thousands of dollars and prevent significant runoff discharge to waterways. More efficient fertilizer and pesticide use can further reduce costs for operators by minimizing the needed amounts of these products. It is difficult to estimate the economic value of this project. However, seminars often charge $500 per person. With 300 attendees, a $150,000 grower benefit would be gained before expanding reach via the website and Guide. The value to growers, factoring the costs above, given increasing regulatory encroachment, will far exceed the project cost.

Lessons Learned

The Guide was developed to present the most current information available on erosion control management in order to give growers options in meeting Waterboard requirements. Research indicated that existing erosion control manuals did not provide installation information or would only provide a few BMPs specific to a unique purpose. This Guide includes all known BMPs for vineyard and orchard operations to provide field crews with a shovel-ready solution in one document as well as providing information on the correct solution for individual erosional problems.

It was also important to provide a Guide that would be useful to field crews. As the majority of vineyard and orchard field crews are Spanish-speaking, translation into their native language was welcomed and reaches the intended audience. This combined approach has been met with great reviews by growers. Agricultural field workers, who are responsible for installing and maintaining erosion control practices, have typically not had instruction on erosion control management or practice. This Guide fills that void. The project reinforced how important it is to know the intended audience and how best to provide relevant information. The initial outreach had been toward vineyard owners and managers. The next phase will be to reach out to the field crew managers and workers directly.

It is too early to discern how helpful the Guide will be to assisting operators in meeting Waterboard requirements. The Waterboard requirements have just recently been adopted so it remains to be seen if operators find this Guide useful. Staff have learned that operators are interested in more workshops and trainings for crews and will continue to work with project partners in providing that information.

This project has reinforced the knowledge that education is more effective than regulation.

A few project elements which staff would include or change:

- Include social media in outreach efforts.
- Include more information on technical methods available for monitoring vineyard/orchard conditions. Many vineyards have incorporated highly technical instruments and science-based approaches to management practices. The Guide should include information on these approaches in future iterations.
- Tracking project success by increases in knowledge levels was difficult to manage and subjectively biased. Future surveys should be designed to more effectively capture the level of efficacy of the project.
- Include tailgate meetings with Spanish-speaking instructors for field workers.

The Ag Department had several unexpected complications which delayed the project. The following discussion illustrates the inability to recover time lost and the impacts on this project.

Loss of staff: The Ag Department experienced the loss of several staff members prior to grant award. Those members were key participants in grant performance and though the Department did hire new staff for those positions, the time lost was critical to publication and outreach efforts. Loss of staff also diminished available resources for this project.

Delayed progress: As a result of staffing issues, development of the Land Steward's Guide was delayed significantly. Peer review and publication of the final draft was further delayed by the devastating October 2017 wildfires which occurred in Sonoma County. Immediately after the fires, the Ag Department staff were re-directed to emergency response and further progress on the grant was halted. Reviewers likewise were impacted by the fires. Consequently, the Guide was not available in printed or electronic form for the December 2017 Growers Meeting. The Ag Department lost the opportunity to distribute copies and to record website hits associated with exposure at the Growers Meeting. These were the only deliverables not met as expected.

The following deliverables were not met:

Website tracking/downloads – Staffing issues and wildfires severely impacted the time necessary to perform outreach. As a result, website hits were not achieved. The Ag Department instituted a webpage counter after publication of the Guide in early 2018. The County Information Services Department was not able to track individual downloads without significantly modifying the Ad Department website, adding a six to eight week delay in tracking. Therefore, the Ag Department was able to track website hits only. Due to the delayed nature of the project, website hit tracking began in December 2017 and ran through November 2018. A total of 127 hits on the Guide were recorded. The Ag Department made every effort to increase awareness of the Guide availability, through Farm Bureau newsletters and e-blasts through partners, but website traffic did not significantly improve.

No summary of events (attendance, outcome, lessons learned) have been posted to the Ag Department website. No additional space was available to include this information on the Ag Department website. The original repository of this information was the Land Stewardship Division webpage which has yet to be developed pending additional funding.

Additional Information

The Land Steward's Guide to Vineyard and Orchard Erosion Control (English):
https://sonomacounty.ca.gov/Agriculture-Weights-and-Measures/News/The-Land-Stewards-Guide-to-Vineyard-and-Orchard-Erosion-Control/

The Land Steward's Guide to Vineyard and Orchard Erosion Control (Spanish):
https://sonomacounty.ca.gov/WorkArea/DownloadAsset.aspx?id=2147558718

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
25	Nut Safety School	
Grant Recipient: AgSafe	**Grant Agreement No.:** SCB15025	**Date Submitted:** December 2018
Recipient Contact: Theresa Kiehn	**Telephone:** (209) 526-4400	**Email:** Theresa@agsafe.org

Project Summary

The Nut Safety School grant project was developed in response to a critical need within the nut industry. The global nut market has experience tremendous growth in recent years, with California's crop value increasing more than 600 percent in the last 10 years alone. California's Mediterranean climate is ideal for growing almonds, walnuts, pistachios, pecans and, as a result, nut growers and processors have been working at a breakneck pace to keep up with burgeoning global demand. This has created a need for improved technology, production efficiency, and knowledge of how to grow the highest quality nut with the least amount of inputs. Subsequently, this labor-intensive sector has needed to invest time and dollars into training its workers in how to grow better nuts faster and in the safest manner possible. Many nut growers and processors have dedicated energy into "how" but not enough investment has been made into "how to safety." This production growth has led to an increase in employment needs and with more employees come greater risk. The National Institute of Occupational Safety and Health reported that a majority of traumatic injuries and deaths in agriculture have been caused by machinery and most notably involved tractors, a critical tool in nut production. This industry's rapid growth created a need for the development of a holistic occupational safety program.

This project was the first of its kind, as it created a foundation for worker safety in the industry. AgSafe, along with project partner Western Agricultural Processor's Association (WAPA) created an interactive training series in English and Spanish addressing critical worker safety issues during almond, walnut, pecan, and pistachio pruning, harvesting, and year round operations. The courses developed provided legally compliant, best practices that specifically addressed how to safely grow, harvest, and process nuts. The trainings included custom harvesting equipment safety overviews, how to use hand-held tools, proper use of personal protective equipment, such as respirators, eye goggles, and hearing protection. The purpose of this training was focused specifically on providing quality technical training to workers, but was not intended to include broader upper management-level discussions, such as creating safety programs. AgSafe and WAPA firmly believed this worker training needed to be in place prior to working on providing guidance on developing company policies. The ultimate objective was to provide California nut growers access to robust safety training for their workers that would result in production efficiencies including fewer worker accidents and fatalities.

California's nut industry is one which is highly mechanized which has led to greater efficiencies, but can also pose a danger for not only those operating the equipment, but also the individuals working alongside equipment such as custom harvesters and tractors. When workers have an incident with this type of machinery, injuries tend to be fairly severe. According to the United States Department of Labor's statistics, between 2002 and 2015, there were 75 serious injuries and or fatalities that occurred in California's nut tree operations. Injuries and fatalities consisted of employees being crushed by a tractor, coming into contact with a power line, and amputated fingers in a sweeper. This data reinforced the critical need for a worker based

training to help ensure that these men and women working tirelessly to grow and harvest California's nuts would leave at the end of their shift healthy and whole.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The following activities were carried out to ensure the goals and intent of the project were carried out to its fullest capacity:

Curriculum Development and Updates

The most crucial element was to create the curriculum for the Nut Safety School. When this project was initially started, the curriculum was slated to consist of three to four hour workshops delivered in both English and Spanish on the topics of pruning, harvest, and year-round operations. Through the course of this project, curriculum updates and modifications were made to combine the topics into one longer session. These topics were also developed into a webinar format to make it more accessible (http://www.agsafe.org/nut-safety-school/). These changes were made to provide the nut industry with a number of different options and formats in which to receive this critical safety education.

Knowledge Assessments

AgSafe and WAPA believed it was important to demonstrate an increase of knowledge amongst participants after attending each workshop. Pre and post knowledge assessments were created utilizing descriptive research mythology while ensuring uniqueness and alignment within the areas of competency. These knowledge assessments were distributed during workshops and data was collected. However, it became evident that the Spanish classes were struggling with the knowledge assessments. Initially AgSafe and WAPA overestimated the ability of the participants to read and write in their native language. An audience response system was purchased in order to address this issue. The audience response system allowed questions to be built into the presentations. Participants were then able to answer using a remote, rather than having to write the answers out. The project team hoped that the use of this system would provide more accurate data and that more people would be willing to participate in this evaluative tool because it was less intimidating. The audience response system was utilized in April of 2018 and was found to elicit greater participation. It also made data summariazation easier. Additionally, real time feedback was gathered during the session. This enabled the instructor to spend additional time on topics the participants struggled in answering questions. The project team plan to incorporate the use of this system into the English speaking classes as well to further enhance the overall learning process and data collection.

Marketing

AgSafe and WAPA leveraged existing networks within the industry to market classes to the nut growers across the California's Central Valley. A multi-tiered approach was used which included postcards, eblasts, social media. Businesses were also contacted through personal emails and phone calls. The project partners also leveraged their relationships with agricultural trade media and advertised classes through publications.

Training Delivery

Through the scope of this grant, AgSafe in collaboration with WAPA provided a total of 33 in-person workshops across the Central Valley. Locations were chosen based upon the greatest concentration of nut production.

Locations for classes conducted between 2016 to 2018 included:

- Chico
- Stockton
- Ceres
- Fresno
- Delano
- Bakersfield

Nut Safety School workshops were develivered in both English and Spanish and included the following:

- Harvest Safety
- Pruning Safety
- Year Round Safety
- All in One (combination of Harvest Safety, Pruning Safety and Year-Round Safety)

Post Assessments Surveys
Post assessment surveys were distributed to companies six months after the course. Email and mail correspondence was sent to workers' managers as identified in their training registration. The purpose of the post assessment survey was to determine if employees were utilizing the knowledge learned during the workshop in their daily routines.

The curriculum developed addressed the unique characteristics of harvesting, pruning, and year-round operations of specialty crops, specifically almonds, walnuts, pecan and pistachios. As such, these trainings would have only benefited those operations which grew these crops, as well as farm labor contractors whom provided labor to harvest, prune and other year rounds needs specific to growing nut crops. All grant expenditures were also tracked to ensure that funds were used to solely enhance the competiveness of specialty crops.

WAPA took the lead in developing and analyzing the pre and post assessment surveys, as well as the six-month evaluation. In the development of this grant it was extremely beneficial to have a third party engaged to administer the evaluation process. Knowing that AgSafe was not directly involved in the evaluation process, allowed participants to be much more candid in their responses. Additionally, WAPA was instrumental in providing curriculum support by reviewing materials, assisting with outreach to the industry, securing demonstration equipment and providing additional onsite support at workshops.

Goals and Outcomes Achieved

The overall goal of this project was to improve the technical knowledge of nut workers in the safe operating practices associated with pruning, harvesting, and year-round maintenance of almonds, walnuts, pistachios, and pecans. Using data gathered via pre-training assessments, post-training assessments, and the implementation survey, AgSafe could measure knowledge gain and retention of workers attending the Nut Safety School.

As mentioned previously AgSafe, along with project partner WAPA, developed a robust baseline safety curriculum for the nut industry. By utilizing existing networks, AgSafe and WAPA promoted classes

throughout the Central Valley, which was where a majority of California's nut operations were located. A total of 33 workshops were held, 4 webinars were conducted, and 2 webinars were recorded.

This project was the first step in developing training specifically for the nut industry. While this project did not have long term goals associated with it, it has gained momentum and more organizations have begun requesting the training created through this grant. In fact, since the trainings were launched, nine agricultural operations and organizations (mainly local farm bureaus) have requested for AgSafe to provide the training specifically for their workers or members. An additional 90 people were trained through this avenue. This trend is anticipated to continue in the years to come.

Additionally, AgSafe's Education Team wrote a number of articles based upon the curriculum developed. These articles have appeared in numerous county Farm Bureau newspapers, as well as West Coast Nut magazine. AgSafe was invited to speak at the Annual Almond Board Conference in December of 2017 (approximately 75 attendees). Partnerships were also developed with companies such as Blue Diamond as well as other nut grower associations. These partnerships and opportunities to connect with the nut industry groups would not have been possible without the work completed through this grant.

Participation
The initial goal was to provide this training to 1,350 individuals, however 436 individuals were trained wthin the duration of the grant, which was 30 percent of the project goal. Low intital participation numbers were attributed to an overall lack of labor in California specialty crops. Agricultural labors has been in high demand in California. Operations that were able to provide year-round, stable work have been more likely to secure the workforce needed to plant and harvest their crops. Nut crops do not fit this scenariro, as the season is relatively short compared to other specialty crops, and as such, have struggled to find enough labor to tend to the operations.

Pre and Post Knowledge Assessments Results
The anticipated target for successful implementation was that a minimum of 75 percent of workers would demonstrate an improvement in their understanding of safety procedures following participation in a training.

Percentage of workers whom demonstrated an improvement in their understanding:

- Harvest Safety: 95 percent
- Pruning Safety: 89 percent
- Year-Round Safety: 97 perceent
- Nut Safety All in One Course: 98 percent

Implementation Survey Results
The anticipated target was a minimum of 60 percent of managers responding to the survey would observe an improvement in the frequency and effectiveness of safety procedure implementation by training participants, as well as other positive impacts to the business.

Survey results demonstrated that 90 percent of those whom responded, reported there was an increase in understanding of safety practices and that the tools and resources provided during the workshops have been used in their operation. Additionally, 85 percent of respondents acknowledged that their employees began

demonstrating safer work practices because of attendance in the workshop. The purpose of the grant was not to create baseline data for the nut industry. However, it was discovered that major injuries and fatalities in nut operations decreased from 18 percent to 13 percent during the span of this grant project.

Highlights of the grant included:

- Developing comprehensive curriculum for the nut industry which previously did not exist.
- Providing 33 workshops over the course of 2.5 years.
- Modified in person training curriculum into a webinar format.
- Developed training tool kits and provided additional resources to the industry that could be accessed even after the duration of the projecect.

Beneficiaries

This project did not translate to many other specialty crops and as such, the majority of the project beneficiaries were comprised of the nut industry. This project enabled the nut industry to create a foundation in safety training and dedicated resources so that the workforce can be provided the necessary education to ensure all are equipped to stay safe on the job.

The number of individuals trained through this project reached 436. This number has the potential to grow as AgSafe has dedicated resources created as a result of this grant located on their website. Included in those resources were recorded webinars, presentations and safety checklists. As previously mentioned, AgSafe intends to continue offering these course beyond the duration of this grant.

Lessons Learned

Through the course of this project, technology continued to improve and AgSafe and WAPA saw an opportunity to utilize a digital format to provide training to the nut industry. While the best education comes from in person training, it is not always practical and convenient. Webinars were a cost effective, easy way to provide training and have the potential to reach more people in the nut industry. The webinars that were created will continue to be available to download on the AgSafe website at no cost well beyond the duration of the grant.

As mentioned earlier in this report, the literacy issue impacted evaluations, was unepxected. However, the project team was able to come up with an innovative solution with the utilization of an audience response system. This system has allowed participants to freely contribute in workshops. The audience response system also helped to provide real time feedback, allowing instructors to spend more time on topics that proved to be more difficult, it also made data summarization easier. AgSafe will continue to use the audience response system in other training, which will continue to benefit California’s specialty crops.

AgSafe and WAPA had a number of discussions regarding the lack of anticipated participation in the Nut Safety School Workshops. The drought and lack of labor in the agricultural industry were determined to have had a very real impact on this project. The lack of water in 2015 and 2016 forced some farming operations to consider removing orchards and replace them with crops less water intensive crops, or choose to let the ground remain fallow. Additionally, labor was, and continued to be, in high demand in California and operations that could provide year-round work were more likely to secure the workforce needed to plant and harvest their crops. Nut crops do not fit into this scenario and as such, have struggled to find enough labor to

tend to their crops. As a result, the lesson here was to ensure that in person workshop were not the only strategy to educate individuals. It was important to diversify and provide a number of avenues for people to receive and access education, resources, and tools.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 26	**Project Title:** Improving Competitiveness of Small and Large California Blueberry Farms through Grafting	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB15026	**Date Submitted:** December 2018
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Project Summary

Blueberry production in California requires soil acidification to produce high yields, as blueberries are adapted to low pH soils. Acidification can be prohibitively expensive for small farmers and economically disadvantaged farmers. Previous research demonstrates that grafting of productive blueberry genotypes onto rootstocks of the high pH tolerant *Vaccinium arboreum* (*V. arboreum* or sparkleberry) is a viable means of adapting blueberry to local soils. Grafted plants would eliminate the need for acidification. This could make blueberry production for local direct marketing possible for small farmers in underserved communities. It would also benefit large-scale producers by eliminating acidification costs and facilitating mechanized harvesting, since grafted varieties have a single trunk. This project evaluated growth of grafted blueberry and investigated mechanisms limiting yield for blueberry in high pH soils, as well as trained small farmers in a grafting of blueberries for local marketing.

Blueberries are a nutritional powerhouse. Blueberry production in the United States is high, but is limited by the period of the year that blueberries are available (spring). For the early spring market demand, California has become a major source of blueberry production (with 60 million pounds per year), with large potential for development in the future. Given the limitations posed by the high pH soil in California, this project was well timed to provide insight into how blueberries can be better adapted to California, at a time that demand for more blueberries was/is high.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Physiology greenhouse investigation

The project manager (PM) and graduate student (GS) performed work on determining the location and mechanism of low pH adaptation in blueberries and the high pH tolerant sparkleberry. The aim was to use this information to determine the ways in which the sparkleberry rootstock is beneficial. Iron is typically the limiting nutrient for low pH adapted plants and thus the focus of the grafting work. The GS successfully evaluated the ability of blueberry and sparkleberry to reduce iron (Fe) when this element is limiting in the solution though measuring the activity of the Ferric chelate reductase (FCR). Both species appear to have similar abilities to reduce iron. Both blueberry and sparkleberry were shown to have similar ability to decrease pH in the soil water solution – a key difference in many other high pH sensitive plants. Subsequent work by the PM and GS has involved pulse experiments where xylem sap is monitored to determine under which soil conditions iron is taken up. To date, the results indicate that both species are able to decrease pH in the xylem, which indicates that shoot mechanisms of iron uptake are unlikely to be limiting to iron transport from roots to leaves.

Physiology field trial
A field trial was planted in Davis, California, aimed at controlling the application of iron and varying pH to the blueberries/sparkleberries and cross grafts. A pot-in-pot system was used to increase control of the soil pH, and is realistic as it is a viable commercial production system for blueberries in adverse conditions. The grafts performed in the pot-in-pot system installed in the field in Davis survived with a rate of 20 percent interspecies (blueberry onto sparkleberry and sparkleberry onto blueberry). The rate for sparkleberry onto sparkleberry was 55 percent and blueberry onto blueberry 85 percent. This is a major finding showing the high interspecies incompatibility that makes it necessary to graft a large amount of plants to have successful numbers of grafted plants. This issue is likely to be of impact to commercial growers, and likely needs to be solved by nurseries supplying already grafted blueberries onto sparkleberries. However, this trial has shown that blueberry plants can grow without soil acidification nor grafting by using an adequate fertigation solution and using (sand + bark + peat) as a non-soil substrate.

A major additional experiment was performed to evaluate whether the deep rooting pattern of sparkleberry had a water-related advantage for grafting to the shallow rooted blueberry. Both species showed a surprising degree of adaptation to drought and stress. The grafting did not appear to improve blueberry response to drought. While sparkleberry had improved shoot hydraulic characteristics, when compared as stem water conductivity little difference was found. This indicates that grafting sparkleberry to blueberry does not have major impact on water relations.

Planting of variety field trial
Given the incompatibility of the rootstock, the many varieties were not grafted in Davis, instead the high/low pH experiment was conducted on plants of the two species in Davis. However, the three varieties originally grafted in Kearney (Jewel, Star and Emerald) were grown and grafted in Davis to understand nutrient dynamics in a broad range of blueberry genotypes. In addition, the harvest season was monitored for the variety trial (22 varieties) that exists in Kearney. This trial has been maintained through this project as a blueberry diversity resource.

Phenology monitoring
Phenology and nutrient data has been collected for the duration of the project by the CA, GS and two research assistants at Kearney and is being analyzed. The phenology and growth data for blueberry and sparkleberry has shown that the two are mismatched relative to timing of growth, with sparkleberry growing late in the season. Future work might focus on finding rootstocks that have high vigor earlier in the season. The nutrient work has shown the advantages of the rootstock at taking up specific nutrients such as (Fe, Zn and Mn). However, these rootstock advantages do not appear to be positively impacting blueberry leaf nutrient concentration. Thus, it remains unclear how the rootstock improves blueberry production. These results are being collated into a paper for a horticultural journal.

To validate the above results, the new field trial at Davis was used and the PM and GS monitored phenology and physiology in blueberry and sparkleberry plants under two pH treatments (5 and 7). This evaluation will continue and includes monitoring xylem pH, leaching pH, growth and foliar nutrient concentration.

Acknowledgement: It should be noted that considerable results from the current project were based upon an existing trial that was originally planted and maintained by the University of California, Agriculture and

Natural Resources along with original funding provided along with plants by Oregon State University and University of Florida. Without this original trial the current project would have lacked a major resource.

Project dissemination
The Co-Applicant (CA), UCCE Fresno and Tulare, organized a great field day in 2018 for small farmers to experience grafting with blueberries and educate them on the technique. A full report is given in Additional Information.

The GS presented results from the present investigation during the "Grafting field day" organized by the CA on 3/21/18. The water relations research is in preparation for publishing. The results have been presented at two conferences the American Horticultural Society conference and the International Vaccinium Symposium in Florida.

The project was aimed at blueberry production through grafting to a related species. While the technology might be useful for other low pH adapted specialty crops, the research was not applied and likely does not apply to non-specialty crops.

The UC Davis GS, provided considerable input into the project at both the Davis and Kearney site. The CA provided on-the-ground project supervision at the Kearney site, and coordinated comprehensive extension activities and the work of student assistants (SA's). The applicant coordinated work and Davis and performed work with the GS at both sites.

Goals and Outcomes Achieved

Activities completed
Yields and economic costs: Under conditions of no soil acidification at Kearney research station, the growth, fruit characteristics, and nutrient concentrations of grafted and ungrafted blueberries were similar. Thus, grafting appears to have minor advantage in terms of growth related results. While this is surprising, it is difficult to evaluate relative to more favorable results in other states with considerable difference in climates and soil conditions. However, it should be noted that the lack of advantage does not imply a disadvantage, and thus other factors, primarily economic ones, may lead to the adoption of grafting. A likely outcome is that the typically multi-stemmed blueberries will be grafted to the single stem of a sparkleberry, and this will improve farm economics due to less labor intensive mechanical harvesting.

Knowledge of mechanism of grafting advantage: This was pursued in a number of avenues, including all nutrients, water and a specific focus on iron uptake physiology. Sparkleberry was able to accumulate more of some nutrients in its leaves (Fe, Zn and Mn), but did not appreciably increase nutrient concentration in blueberry leaves when grafted. This likely indicates that these differences in physiology were in the shoot, not roots, and thus were not transferred to blueberry. Blueberry was relatively well adapted to water deficit, and was not advantaged (or dis-advantaged) by grafting to the considerably different sparkleberry. Iron uptake physiology is still being finalized, but the results indicate that both species have similar soil pH oxidation abilities, similar ferric chelate reductase activities (an iron uptake related enzyme), and somewhat similar abilities to transport iron in the xylem (i.e. once taken up by the roots).

Expand selection of blueberry scions: The diversity trial at Kearney has a broad diversity of adapted and unadapted blueberries originating from across the United States. These were monitored to evaluate which

produced well and had a broad range of harvest dates – a key factor for market share for local blueberry farmers. A table illustrating these results is attached (Attachment 1). Related to this goal was the training/adoption by small farmers. A field day focused on grafting training and education. The results of survey's (given in Additional Information) illustrates strong results, although it is too soon to evaluate long term adoption.

Access to blueberry germplasm: The project enabled the maintenance of the valuable diversity collection at Kearney to date. The monitoring of fruiting, mentioned above, provides a key to the use of this trial.

The field day (2018) and results from this project were made available recently, while these had very positive responses (see Additional Information) it is unclear what long term trends will be relative to this project. It seems likely that grafting will become more prevalent as labor issues become limiting to blueberry harvesting.

Accomplishments
Yields and economic costs: Growth, fruit characteristics and nutrient differences were monitored between grafted and ungrafted blueberries. Obtaining quantitatively relevant yields that are applicable to commercial production systems were not possible due to the poor cross species grafting compatibility mentioned above. Given the lack of differences in growth and nutrients, it seems likely that yields are not substantially different between treatments. A five to 25 percent decrease in blueberry cost production was not achieved.

Knowledge of mechanism of grafting advantage: The determination of differences in iron physiology (and other nutrients like nitrogen) between the species was largely achieved through greenhouse experiments. The poor cross species grafting compatibility forced the Davis field trial's focus to be on the differences between species, and not focused on the location of differences (i.e. roots versus shoots). A five to 25 percent decrease in costs due to no need for soil acidification was not achieved.

Expand selection of blueberry scions that graft well and have a range of harvest dates for small farms: The goals were partially achieved. Re. the outreach for grafting to small farmers, the highly successful field day and extension activities of the CA are commended. Adoption data is not ready this early in the process. The CA continues to be involved in this community and will be able to provide this information after one to two years.

Access to blueberry germplasm: While the project has maintained the collection of blueberry germplasm to date, the resource has now been returned to the Kearney Agricultural Experimental Station for future care. Future external funding will likely be necessary to maintain this collection, it is unclear where this will come from. Obtaining $10,000 per year from California blueberry growers has not been achieved.

Progress towards achieving set targets
Data on iron uptake[…]: Was evaluated in the greenhouse/laboratory as an alternative to the Davis field trial which switched focus to species comparisons.

Data collected from the physiology field trial[…]: A large database of macro and micro-nutrient contents of blueberry, grafted and ungrafted has been compiled for multiple times of the year and over two years, matching growth data at the Kearney trial. This dataset will form a baseline for recommendations of application and timing of nutrients. A manuscript is being written to disseminate these results (Hernandez, I.

and Gilbert, M.E. *Timing of nutrient uptake and growth in grafted blueberry and the sparkleberry rootstock*) and will be submitted to the journal HortScience by the end of 2018.

Iron isotopic fractionation experiments[…]: This outcome was not achieved due to issues with analysis of iron stable isotopes with inductively-coupled-plasma spectroscopy, and calculations that showed that the stable isotope signal caused by different iron uptake pathways would be small. Alternative physiological assays were performed using pulse experiments in the lab.

Data will be collected in the foliar nutrient application or chelation experiments[…]: Due to blueberries achieving sufficient nutrient concentrations in the grafting trial, the focus was put on chelation experiments which could be applied via drip fertigation/irrigation systems such as those used at the Davis trial. Different iron chelators were evaluated and ethylenediamine (EDDHA) was determined to be the best for Californian conditions. Growth in the Davis trial showed that this chelator was a good source of iron at high pH.

Timing of fruiting[…]: Phenological monitoring was completed for both the Kearney grafting trial and diversity trial. This data is attached as a table listing each variety adapted to Californian conditions.

Yield measurements[…]: Growth, nutrient analyses and fruit quality characteristics were performed in all appropriate experiments. Yield under grafting was not evaluated as explained above.

Maintenance of a database[…]: See the results of the survey's in Additional Information. The measurement of how many farmers adopted the practice is not available this early.

Field day attendance: See the description of Extension Activities in Additional Information.

Blueberry has similar nutrient uptake and water physiology to the rootstock. While this indicates some physiological compatibility, the rootstock has a different growth habit and showed grafting incompatibility. The rootstock did not substantially improve blueberry growth and nutrient uptake in California. Despite the apparent lack of advantage for grafting, the rootstock may have more value in allowing mechanical harvesting of blueberries – a major economic bonus. Fruiting timing and adaption to the Central Valley of California are now available for 22 varieties of blueberries.

Beneficiaries

As detailed more fully in 'Extension Activities' in the Additional Information section, considerable numbers of small farmers, attended blueberry grafting educational events led by the CA. The 'Extension Activities' describes the high impact had on attendees with regard to knowledge about grafting and future acceptance of the technology. The GS has been to a number of large blueberry nursery and industry organizations and has discussed project results. The research has also been presented at an American Society Horticultural conference and at the International *Vaccinium* Symposium in Florida – both state of the art venues for blueberry research dissemination.

One hundred and eight (108) people, including Spanish, Laotian and Hmong farmers, participated in a blueberry grafting education activities led by the CA. Additional outreach occurred via outreach on the Hmong radio station and a booth at the Black Farmers Conference in Fresno.

The blueberry production community in California comprises about 5,700 acres (United States Department of Agriculture 2015 National Agricultural Statistics Survey). Most of this is of moderate sized farmers, so a considerable number of blueberry farmers could be impacted by the results of this study. The savings realized through eliminating the cost of acid application is $200/acre annually, meaning a potential savings of $1.1 million annually.

Lessons Learned

A major limitation to the activities of the GS and PM, both at Davis, was the large travel distance to Kearney farm. This meant that routine experiments and maintenance were difficult. Staff solved this issue by focusing the activities of the CA and student assistants, based in Fresno, on the Kearney trials, and shifted the planned Kearney trial to Davis. This enabled daily monitoring and maintenance of the fertigation system and plant physiology by the GS. The expert knowledge of UC Davis greenhouse/farm staff allowed the pH and fertigation system to be implemented without the originally anticipated high costs.

The UC Davis trial demonstrated that pot-in-pot growing systems (50 gallon pots recessed in the soil) are feasible for growing shrubs like blueberries where root depths are typically limited. This may be a feasible option for small blueberry farmers who would like to cultivate blueberries in adverse soils.

A key finding of the research was that blueberry and its rootstock have a degree of incompatibility. This makes grafting of the plants quite difficult to achieve, although it is still practical. Thus, future research/application of grafting in blueberry needs to focus on grafting in commercial greenhouses with subsequent out-planting. At least, practitioners need to be careful with the grafting step of the production process.

Additional Information

Extension Activities

Two outreach events were organized by project CA to educate small-scale farmers about grafted blueberry techniques and extend results of research. A field day focusing on hands-on grafting training was held on March 21, 2018 at the Kearney Agricultural Research and Extension Center in Parlier, California, and information on grafting blueberry plants and results of research were presented at an extension meeting on June 6, 2018 in Fresno, California. Both events provided translation in Hmong, Lao, and Spanish. Attendance was 68 participants at the March 21 field day and 40 participants at the June 6 meeting. Outreach to promote these events and discussion of project results were conducted through regular Hmong radio programming and through an information booth and presentation at the Black Farmers Conference in Fresno on February 28, 2018.

Participants in the grafting training on March 21 were asked to complete an anonymous evaluation following the workshop. The evaluation included post-pre survey questions to document challenges for small-scale blueberry production and measure knowledge gained from workshop presentations and demonstrations. The post-workshop evaluation was completed by 37 growers, who reported an average farm size of 17.08 acres, with a range from one to 65 acres and a median of 10 acres.

When growers were asked to indicate the difficulty of several production challenges on a zero to five scale, soil acidification had the highest average ranking (Table 1). Both soil acidification and labor costs for hand

harvesting were ranked as more difficult than marketing challenges. When asked if they would adopt grafted blueberry production without the requirement for soil acidification, 65.6 percent of growers indicated yes (Table 2). These results agree with the initial assessment that soil acidification is one of the most difficult challenges in blueberry production for small-scale farms.

Participants in the grafting training reported increases in knowledge from 164.4 – 361.5 percent on all topics covered in the presentations and demonstrations (Table 3). The highest percentage increases in knowledge were for grafting techniques and production with grafted blueberry plants. These two topics were also those that participants had the lowest familiarity with before the training. The low reported knowledge on all topics prior to the training and the high reported knowledge after the training indicate that this population of growers could greatly benefit from further training on grafting techniques, plant propagation, and grafted blueberry production.

Table 1. What would be the most important challenges for you to grow blueberries on your farm? (Responses ranked from 0 – 5, where 0 = not a problem at all and 5 = very challenging) (N = 36)

Challenge	Average ranking
Too complicated to acidify the soil	3.64
Labor costs to harvest by hand	3.38
Not having a market to sell to	2.77

Table 2. Would you grow grafted blueberries on your farm if you did not have to add acid to the soil? (N = 32)

Response	% of respondents
Yes	65.6
No	9.4
Maybe	25.0

Table 3. How much did your knowledge increase about each of the following topics? Responses ranked from 0 – 5 for each topic, before and after the training (N = 31) (0 = no knowledge 5 = high level of knowledge)

Workshop Topic	Average knowledge before workshop	Average knowledge after workshop	% increase in knowledge
Plant Anatomy for Grafting	1.33	4.03	202.5
Sanitation Techniques	1.5	3.97	164.4
Grafting Techniques	0.97	4.13	327.6
Selection of Budwood	1.03	3.93	280.6
Grafted Blueberry Plants for Production	0.83	3.87	361.5

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 27	**Project Title:** The Importance of Bees	
Grant Recipient: Manteca Unified School District	**Grant Agreement No.:** SCB15027	**Date Submitted:** December 2018
Recipient Contact: Cole Dutter	**Telephone:** (209) 456-0353	**Email:** cdutter@musd.net

Project Summary

Manteca Unified School District (MUSD) is located in the San Joaquin Valley and is surrounded by specialty crops in need of pollination. The local apiculture industry is suffering from an aging population of beekeepers, with an average age of 55. Local farmers are forced to use beekeepers that are out of the area due to the lack of a local supply of pollinators. Subsequently, there are relatively few local sources of honey near Manteca. This project has two approaches to this problem. The first approach was to train a new generation in apiculture with an emphasis in pollination. Ten students from the five Future Farmers of America chapters in MUSD and one college student from California State University, Stanislaus (CSU Stanislaus) were chosen to participate in this project. The high school students were chosen based on interest in apiculture and recommendations from their teachers. The college student was chosen based on interest in apiculture and desired career path. The training of these students included beehive care through all seasons, starting new hives, monitoring during pollination, and harvesting and bottling honey. The second approach was to increase the supply of local honey. Manteca and the surrounding towns have only obscure sources of local honey. This approach to the project allowed families in MUSD to be able to buy local honey, and many of these are low-income families. Because of its location, MUSD is perfectly positioned to help both its students, by giving them vocational training, and the bee industry, by supplying a young, trained workforce to the apiculture industry at a time when trained, local, conscientious beekeepers are needed. Overall, the objectives of MUSD for this project were to supply vocational training to students, expose students to the apiculture industry (the concerns, benefits, and value of pollination), demonstrate the business opportunities within apiculture, train students to be advocates for pollinators, and increase the local honey supply.

The Importance of Bees is a project aimed at training and equipping the next generation of beekeepers. The project included technical training in the management practices of beekeepers, economic training in how to own and operate an apiary business, and environmental training in how to care for pollinators with a sustainable method. The technical training included monitoring hive health, mite inspection, implementation of mite control, honey harvesting, overwintering techniques, and general best management practices of pollinating. The economic training included budgeting resources for necessary supplies, marketing for pollination services, marketing of honey, threshold of action for mite and disease control, and decision making on the margin. The environmental training included educating students on the needs of pollinators, the value of pollination services, how to evaluate overwintering sights, and chemical-free beekeeping. All of these were done with a hands-on, vocational approach for the students. This trained students in the technical and economic skills to be the future workforce for the apiary industry. The students were given a stipend while working in the program and were exposed to the economic opportunities in the apiculture industry. The possible career paths, economics of beekeeping, and low startup costs would attract students to this industry. This will give the local beekeeping industry, as well as the specialty crops supported by pollination, long-term viability. This project has an additional benefit of reaching the high population of low-income families

in the district with the availability of this vocational training, in addition to increasing the supply of reasonably priced local honey.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The activities and tasks performed during the grant period are as follow:

- Initial survey of honey sellers at local farmers' markets
- Initial survey of beekeepers in San Joaquin County
- Selection of initial students
- Base survey of initial students
- Training of initial students
- Second survey of honey sellers at local farmers' markets
- Second survey of beekeepers in San Joaquin County
- Selection of second group of students
- Exit survey of initial students
- Base survey of secondary students
- Training of secondary students
- Third survey of honey sellers at local farmers' markets
- Third survey of beekeepers in San Joaquin County
- Exit survey of secondary students

The project staff had a thriving completion of activities during the entirety of the grant. The training of the secondary students began in March 2016. The students selected always showed great promise and excitement while working with the bee program. Project staff also had one member of the secondary students purchase a hive on their own and has managed the hive outside of the project. The beekeepers survey has shown an increase in local beekeepers in the county from year one to year three. The number of beekeepers has slightly gone up from 24 in the first year of the study to 31 currently in the San Joaquin County. Project staff then went out to various farmers markets looking for local honey sellers to complete the honey survey. In conclusion the number of local honey sellers also increased from two honey sellers to a total of four now. A favorable development that occurred was that The Importance of Bees project is now the main calling point when it comes to catching bee swarms around the community. If any swarms are found on a school site The Importance of Bees project is called immediately. If the city of Manteca gets a call with a swarm located at a resident's home or a city park The Importance of Bees are the first to be called. In total The Importance of Bees project has caught over 20 swarms in three years since the bee project has begun.

This project did not benefit commodities other than California specialty crops.

Burch Bees supports this project because it will keep the industry supplied with new, trained beekeepers. This is preferable because they will not have to train employees on the basics of beekeeping anymore. Secondary Education Department at MUSD supports this project by leasing the beehives from this project once the hives are established for pollination services for its almond farm. The program be.tech at MUSD supports this project because it is in line with their vocational education programs. The Agricultural Studies Department at CSU Stanislaus supports this project because it will add to the diversity of its student training.

Goals and Outcomes Achieved

The activities completed in order to achieve the performance goals and measurable outcomes were as follows; The first goal was to increase local proficient beekeepers. To do this, project staff trained over 30 students from MUSD and gave them hands-on development on how to become beekeepers. The second goal was to increase the supply of local honey in and around the district. This will enhance the competitiveness of specialty crops by maintaining or increasing the supply of honey locally. The activity of surveying local honey suppliers showed project staff that local honey had increased in the area. The third goal was to increase the interest in beekeeping as a profession through all MUSD high schools. Project staff obtained this by the number of applicants received increasing each year for students interested in the bee program.

All the project's outcome measures were long term. The project's first benchmark was to increase two beekeepers in San Joaquin County by 2017, and six beekeepers by 2019. As of February 2018, the project had seen an increase of seven beekeepers in San Joaquin County from the initial survey. The second benchmark was to increase one local honey supplier in 2017 and three local honey suppliers by 2019. After surveying local farmers markets project staff were able to find three different local honey suppliers in the area. The third benchmark was to increase applicants of high school students by 200 percent from each high school, from the initial number of interested applicants. Of the five high schools project staff were able to achieve that goal for three of the five schools.

The first goal was met by training 10 students in beekeeping each year. During the three years of the project, project staff had 30 proficient beekeeping students from MUSD. The second goal was increasing local honey around the district. Project staff were able to harvest honey and provide it to the school cafeteria kitchens. During the project term, the project sold over 200 pints of honey to district officials, teachers, students, and parents of the district. The third goal of the project was to increase the interest of beekeeping as a profession at MUSD. The project met this goal as more and more students applied for the program each year. Teachers who worked on the school farm even became interested and some even bought hives for themselves to keep on their property and begin the beekeeping hobby. The project also had one high school student who has five hives of their own and is working their way up to being able to lease out the hives one day to help with the pollination events around the San Joaquin County area. This student also attends many "Ag Days" around the district to speak about the importance of Honey Bees.

There are three expected measurable outcomes for this project, which are as follows:

1. Increase the number of local proficient beekeepers
2. Increase the supply of local honey in and around the district
3. Increase the interest in beekeeping as a profession through all of MUSD high schools

There was growth in the number of local proficient beekeepers in the San Joaquin County. The number of registered beekeepers in the county started at 27 and increased to 31. The local honey survey showed progress with an increase in local honey being sold from two cities to four cities. Lastly with the continual training of local proficient beekeepers, it has inspired an increased interest in a student from the bee program to purchase their own hive and manage it from home.

The project was able to connect and network with the City of Manteca which led the project to catching 22 bee swarms at local parks, local properties, and city inhabitant's homes. This helped the project ensure the public's safety and keep bees protected by giving them a place to thrive on the farm.

Beneficiaries

The primary beneficiaries for this project are the local specialty crop growers of almonds, apples, cherries, melons, and other small acreage fruit tree crops that need pollination services. This project also benefits the local beekeepers and honey market.

Additional groups and operations that benefited from this project's accomplishments were as follows:

1. City of Manteca – This project led to public safety and helped spread knowledge of bees to the community.
2. MUSD – This project provided local honey to cafeteria kitchens, to staff and parents. This project also provided training and education for high school students on the importance of bees. This project provided local bees to pollinate the 23 acres of almonds which is owned by the school.

The City of Manteca greatly benefitted from having The Importance of Bees project remove bee swarms since they didn't have the tools or a way of doing it safely. The project provided a service that wasn't readily available before. MUSD also benefitted from the project because they now have a way to safely remove bees that are found on school sites and can keep the students safe.

During the grant period, 19 students participated in training program and since the conclusion of grant, 10 more students have been trained. These students are now capable to run their own apiary. The bee program is known throughout the community and school district to collect bee swarms. The program also sold honey to the local community. The total amount of program income earned during the grant period from honey sales was $892.59. The program income was reinvested into the project by covering expenses for additional beekeeping supplies. The number of honey sellers increased in the project's region during the grant period. The beneficiaries affected by the project's accomplishments are: 29 trained students, local community's access to local honey (over 100 lbs. sold to the community), the school farm's pollination for two seasons, over 10 swarms collected throughout the community each season. There is one student who is building an apiary with unknown economic impact at this point and other students are anticipated to follow. The potential economic impact of this project remains quite large as students begin to enter the workforce of agriculture.

Lessons Learned

Some of the insights project staff learned during the project term were as follows:

1. Hive Loss: During the first year of the project, project staff experienced a high rate of hive loss due to a varroa mite attack. The project's hive management improved each year after project staff learned about what worked best for the hives and what didn't. Applying two mite treatments instead of one helped the hives a lot. Project staff also learned that spreading out the hives between different locations helped.
2. Recruitment of Students: Project staff depended on student recruitment by word of mouth from current students and from teachers spreading the word. Project staff should have gone directly to the high schools and handed out information and answered questions themselves.

3. Collaborations: By reaching out to the City of Manteca it helped the project capture swarms which increased the project's hive populations.
4. Hive Placement: Project staff decided to speak out and ask schools to have hives placed on their sites. This helped the project with their hive density issue and helped the project's bees thrive.

The goal of increasing high school applicants by 200 percent was not met at all five high schools. When this happened, project staff noticed that the majority of the bee students were from the same high school. Since this goal was not met, project staff have learned that they should have approached the high school campuses differently and spread the word of The Importance of Bees program in person and straight from the source.

Additional Information

See pictures below:

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 28	**Project Title:** San Joaquin County AgVenture	
Grant Recipient: San Joaquin County	**Grant Agreement No.:** SCB15028	**Date Submitted:** December 2018
Recipient Contact: Kamal Bagri Krista McCoon	**Telephone:** (209) 953-6008 (209) 402-5734	**Email:** kbagri@sjgov.org sjcagventure@yahoo.com

Project Summary

AgVenture is an agriculture and nutrition education program for third grade students with a Healthy Snacks component for fourth graders in San Joaquin County. The overarching goal of AgVenture is to increase youth awareness of agriculture and the health benefits of locally grown specialty crops. The program teaches students about the variety, quality, availability, and health benefits of specialty crops; nutrition in relation to healthy living; and the role students' play as consumers in helping to maintain agriculture as a strong component of the local economy.

AgVenture is important to the specialty crop industry, as it is the only local program of its kind. Local farmers, producers, and hundreds of other volunteers come together to share their knowledge of locally grown specialty crops with over 11,000 third-grade students, teachers, and adult chaperones (usually parents) each year. The Healthy Snack Program component was a new addition to the program and proposed to directly impact over 120 fourth-grade students, their teachers, and adult chaperones each year. AgVenture showcases the county's booming agriculture industry and the hardworking people behind it. Students come away from the program with a better understanding and appreciation for specialty crops and their nutritional benefits.

Additionally, one fourth grade Healthy Snack Program was held each year of the grant period with students coming from different schools throughout San Joaquin County for a total of three events. During each event the participating classes were educated about five specialty crops; including their respective history, nutritional benefits and how each is grown. After the presentations, the students were taught how to make a healthy snack utilizing all the specialty crops.

San Joaquin County is the sixth most productive agricultural county in California and the nation, producing nearly $2 billion in specialty crops annually. Yet, *Searching for Healthy Food: The Food Landscape in San Joaquin County*, a report by the California Center for Public Health Advocacy, found that the county's Retail Food Environment Index (RFEI) was 4.03. This means there are more than four times as many fast-food restaurants and convenience stores as supermarkets and produce vendors. Furthermore, a 2011-2012 California Health Interview Survey (CHIS) conducted by the University of California, Los Angeles Center for Health Policy Research, found that 41.3 percent of children ages two to 17 had fast food at least twice in the last week; only 23.7 percent had five or more servings of fruits and vegetables yesterday; and 38.3 percent of children ages two to 11 and 78.4 percent of children ages 12 to 17 had one or more servings of soda or sugary drinks yesterday. Furthermore, according to the San Joaquin County Community Health Status Report 65 percent of adults in San Joaquin County are overweight or obese, and more than 33 percent of children in grades five, seven, and nine are overweight or obese (San Joaquin County Public Health Services, 2011).

This project built upon the 2012 Specialty Crop Block Grant Program Project 4: *San Joaquin County AgVenture.* The project compliments the previous work through the addition of Healthy Snacks Program the third grade AgVenture program. It reinforced the information provided to the fourth-grade students from the year prior regarding the health benefits of specialty crops. The hands-on approach of the healthy snacks program encourages students to be actively involved as consumers and make healthy choices.

Project Approach

AgVenture:

The following activities were completed in order to achieve the goals and objectives for the program:

- Confirmed locations and dates for Manteca, Stockton and Lodi AgVenture field days.
- Notified all school districts and volunteers with AgVenture event dates for placement on appropriate academic and business calendars.
- Obtained student count information from school districts and schools for AgVenture events.
- Recruited specialty crop farmers, producers, and volunteers to host agriculture and nutrition-based educational presentations and displays for students at AgVenture.
- Developed transportation and event schedules for students from school sites to their respective AgVenture field day locations.
- Developed informational materials and distributed to teachers and volunteers for AgVenture.
- Conducted three free AgVenture field days for third graders in different geographic areas of San Joaquin County.
- Sent out teacher surveys for each event.
- Conducted AgVenture pre/post-tests to determine improvements in student knowledge.
- The Healthy Snack Program Coordinator conducted Healthy Snack events to fourth grade students at six low-income schools from 2016-2018. One event was conducted each year with two schools (five classes total) invited to attend. The events were held in April 2018, May 2017 and 2018, respectfully.
- University of California Cooperative Extension (UCCE) conducted pre and post surveys to the six low-income schools.
- UCCE prepared all produce and ingredients for the three events.
- The Healthy Snack Program Coordinator obtained locally grown produce and conducted meetings with the agriculture education committee to review the program and make suggestions and improvements.

During the grant period, 29,549 students were educated about the health benefits of specialty crops in addition to an estimated 4,650 teachers and chaperones. Over 3,574 volunteers made these events possible. Events each ran as planned and teachers commented in follow-up surveys that they appreciated the variety of displays and hope the program continues. Additional comments were provided regarding what they'd like to see added or modified in the future. Comments included: wanting even more displays including some on honey and melons, having a specialty crop curriculum provided prior to the event to better prepare the students, and wanting more take-home items. A class photo area was set up for students to have a memento of the trip.

Substantial community support and in-kind resources were provided to the AgVenture program. The Manteca Unified School District, San Joaquin County Fairgrounds and Lodi Grape Festival Grounds all donated the use of their facilities for each year of the program. The San Joaquin County Agricultural Commissioner's Office provided 121.25 volunteer hours. The San Joaquin Farm Bureau and California Women for Agriculture, San Joaquin County Chapter provided breakfast and lunch for every volunteer at each event during the grant

duration. Additionally, Bonnie Plants provided a cabbage plant to each student to grow at home. Scotts' Company also provided each class with two bags of soil for growing plants in the classroom. The San Joaquin County Office of Education provided a minimum of ten volunteers per event, Natural Resources Conservation Service provided volunteers at each event, UCCE Service also provided volunteers for the MyPlate presentations. In total, over 18,800 volunteer hours were donated to the AgVenture program during the duration of the grant.

Healthy Snack:
UCCE representative conducted pre/post-tests about student knowledge of San Joaquin County specialty crops with students before and after each fourth-grade healthy snack program. Travaille & Phippen donated almonds, Morada Produce donated cherries and Clements Ridge donated strawberries so students were able to taste fresh and local specialty crops. Furthermore, Sierra Manteca Future Farmers of America and San Joaquin Farm Bureau Federation Board Member's donated their time and volunteered to assist with the program.

AgVenture & Healthy Snack:
While the AgVenture program did benefit non-specialty crop commodities, grant funds were only requested to cover the portion of the program directly benefitting specialty crops, 65 percent of the total. A database was kept regarding the topics of presentations to ensure 65 percent or more were specialty crops. On average, specialty crops represented 71.4 percent of the presentations at the AgVenture events during the grant duration. Therefore, the goal of a minimum 65 percent specialty crop presentations was exceeded.

The fourth grade Healthy Snack program solely benefitted specialty crops as no other commodities were presented to the students.

Goals and Outcomes Achieved

AgVenture:
In order to achieve the goals set forth in the project, a handful of activities were completed, these are described in previous sections of the report. In summary, three AgVenture events per school year were conducted for the third graders in San Joaquin County. Volunteers were recruited to educate these students about agriculture and specialty crops. Volunteers were logged in a database to keep track of the total number of volunteers as well as presentation topics. A pre/post-test was administered and analyzed to determine students' increase in knowledge regarding specialty crops.

The following activities were accomplished for each project goal.

- Third-graders in San Joaquin County were provided the opportunity to learn about locally grown specialty crops, nutrition in relation to healthy living, and the importance of agriculture's role in history and economics. A major project goal was to conduct two field days in year one, and three free field days in year two and three. These field days were to be maintained at this level for the 2015/2016 through 2017/2018 school years. A total of nine AgVenture field days were provided during the grant duration. These events took place: Manteca (November 2015, 2016, and 2017), Stockton (January 2016, 2017, and 2018), Lodi (March 2016, February 2017 and 2018). In total, 29,549 students went through the AgVenture program during the grant period (2015/2016: 9,980, 2016/2017: 9,985, and 2017/2018: 9,584). This goal was exceeded with the completion of these nine events.
- To assess if student nutritional benefits knowledge improved regarding the specialty crops, pre/post-test were utilized. A project goal was to increase student knowledge from 10 percent to 15 percent. For

events during the 2015/2016 school year, knowledge increased by 17 percent. For events during the 2016/2017 school year, knowledge increased by 29 percent. And for events during the 2017/2018 school year, knowledge increased by 27 percent. Therefore, on average, students increased their knowledge of specialty crop nutrition by 24.3 percent.

- During the grant period, student knowledge of the importance of agriculture's role in the local economy increased. Pre/post-tests were used to assess students' knowledge. For events during the 2015/2016 school year, knowledge increased by 18 percent. For events during 2016/2017 school year, knowledge increased by 24 percent. And for events during the 2017/2018 school year, knowledge increased by 26 percent. Therefore, on average, students increased their knowledge of the importance of agriculture's role in the local economy by 22.7 percent. The target goal to increase knowledge by 15 percent, as compared to the benchmark 10 percent, was exceeded.
- During the grant period, a database generated and recorded the number of AgVenture volunteers. For events during the 2015/2016 school year, there were 1,218 volunteers. For events during the 2016/2017 school year, there were 1,180 volunteers. And for events during the 2017/2018 school year, there were 1,176 volunteers. The goal of increasing the number volunteers from 1,000 to the 1,150 was exceeded with an average number of 1,191 volunteers per year.
- While no benchmark exists for recruiting new volunteers, the project goal was set to have 10 percent of the volunteers for each year be new to the program. For events during the 2015/2016 school year, there were eight percent new volunteers. For the 2016/2017 school year, there were 9.3 percent. And for events during the 2017/2018 school year, there were 10.1 percent new volunteers. In total, the goal of 10 percent new volunteers was not met, coming in at 9.3 percent. However, this only represents those who showed up to events, not those who signed up and planned to attend. Last minute dropouts due to flooding and flu resulted in not meeting this goal. With normal years of participation and a less aggressive flu virus season, this goal would have most likely been met.

Having exceeded the goals regarding increase in student knowledge is largely impactful. The bottom line of the program is to educate students about the nutritional benefits of specialty crops. The project was able to meet the two goals pertaining to an increase in student knowledge by a minimum of 7.5 percent. This a major success of the AgVenture program.

Healthy Snack:

The following were the goals and actual accomplishments for each goal set out in the grant proposal.

- A project goal was to identify and provide one healthy snacks program per year to include minimum of five fourth grade classes, approximately 121 students from the county. This goal was met. The program served 445 fourth grade students from fifteen classes and six schools from throughout the county. The Healthy Snack program provided three events participated in by the schools listed below.
  April 2016 - Shasta and Elementary Central Elementary School(s)
  May 2017 – Marshall and Williams Elementary School(s)
  May 2018 – Clairmont and Westwood Elementary School(s)
- Program goal, to increase and reinforce knowledge gained during AgVenture field days. Benchmark: No current baseline knowledge exists. Target: Specialty Crop and nutrition knowledge to increase by 15 percent.

- During the grant period, student knowledge improved regarding the nutritional benefits of specialty crops. For the 2016 event all students correctly identified the nutritional benefits in both the pre and posttests. For the 2017 and 2018 event(s) student knowledge increased by 1 percent.
- During the grant period, student knowledge improved regarding knowledge of specialty crops grown in San Joaquin County. For the 2016 event knowledge increased their knowledge by 16 percent. For the 2017 event knowledge increased by 24 percent. For the 2018 event knowledge increased by 49 percent.

In order to achieve the project goals, a committee was assembled to create the Healthy Snack Program. The program was held once a year over the three-year grant period with a total of two schools/five fourth grade classes per year. Volunteers were recruited to educate the students about the five specialty crops selected and to teach the student's how to make a healthy snack with said crops. A pre/post-test was administrated and analyzed by UCCE volunteers to determine student's increase in knowledge regarding specialty crops.

This program was designed to build on the knowledge gained through the AgVenture program. The students came in to the program with a strong foundation on the nutritional benefits of specialty crops therefore the largest increase in knowledge came with respect specialty crops.

AgVenture & Healthy Snack:
Outcome measures for these programs were not long term.

Beneficiaries

AgVenture:
All those involved benefitted from the AgVenture program. First, the 29,500+ students who went through the program benefitted hugely. Approximately 4,650 chaperones and teachers also benefitted as a resulted of this educational program. Volunteers who participated received benefit from the program by being able to impart their knowledge and passion. Organizations who sent representatives to educate students were able to interact directly with consumers. Some volunteers also received community service credit with the organizations with which they were associated. Finally, specialty crop farmers and producers benefitted by having more informed consumers.

The following are the number of beneficiaries of the AgVenture program:

- 29,549 San Joaquin County third graders
- 4,650 teachers and chaperones
- 3,574 volunteers (specialty crop producers, farmers, FFA/4-H members, industry organizations, etc.)

Healthy Snack:
The 445 participating fourth grade students as well as their teachers and chaperones directly benefited from the healthy snack program. A secondary group of beneficiaries were their family and friends whom the information experience was shared with. Lastly, the project volunteers and partners benefited by being able to participate in this program. Finally, specialty crop farmers and producers benefitted by having more informed consumers.

The following are the number of beneficiaries of the AgVenture program:

- 445 San Joaquin County fourth graders
- 25 teachers and volunteers

- 27 volunteers (specialty crop producers, farmers, FFA members, etc.)

Lessons Learned

AgVenture:
Overall, the AgVenture events were met with great success. Student knowledge increased by a greater percent than expected. Additionally, through the teacher survey portion, ideas were provided to enhance the program. For example, teachers requested reading book lists or a curriculum that could be provided to prepare students for the event. Weather is always a large factor when preparing for outdoor events. Backup plans for each location should be prepared to ensure the best experience for participants. Also, moving forward, a few backup volunteers should be recruited in order to compensate for last minute cancelations.

Healthy Snack:
For the fourth-grade program, timing was an issue. The project team was forced to adjust the event from April into May due to the availability of specialty crops as well as the availability of the schools and the project volunteers. April is a testing month for many schools so by pushing the event into May the project team was able to receive more donations and better responses from the schools. By also pushing the event into May there was less concerned about the weather and the potential impact of rain.

AgVenture & Healthy Snack:
While there were very few unexpected outcomes of the AgVenture program, there was one of note. Bonnie Plants provided each of the students a cabbage plant to grow at home. During the program, a company representative explained to each class that if the students grow the plants, they can enter the Bonnie Plants Scholarship Program. One third grader from each state is drawn at random for a $1000 scholarship. A student who participated in the Stockton AgVenture program in January 2016, won the scholarship for California. While an isolated outcome, it was a great moment for the program and student. There were no unexpected outcomes for the Healthy Snack program.

All goals and outcome measures were met or exceeded, with the exception of the new volunteer recruitment goal. This was negatively impacted by flooding in 2016/2017 and an aggressive flu virus in 2017/2018. All other goals were met or exceeded.

Additional Information

AgVenture:

Facebook: https://www.facebook.com/sjcagventure/
Manteca Bulletin: DOWN ON THE FARM
Stockton Record: Third-graders go farming, Cabbage Patch Kid, AgVenture: What Happens when 4,000 children visit and SJ Farm, South County Students Introduced to Agriculture
Lodi News Sentinel: http://www.lodinews.com/news/article_745c4af4-e046-11e5-b3ae-57820811d0b1.html

Healthy Snack:
No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 29	**Project Title:** Establishing Online Nuts and Tree Fruit Education Program to Train California Specialty Crop Growers	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB15029	**Date Submitted:** December 2018
Recipient Contact: Carlos Crisosto, PhD	**Telephone:** (530) 752-7549	**Email:** chcrisosto@ucdavis.edu

Project Summary

California nut production increased dramatically due to world-wide demand and low hand-labor costs, while large stone fruit acreage has decreased due to international competition with access to inexpensive manual labor. In addition to market shifts, specialty crop tree growers will need to respond immediately to predicted climate change, greater instability in water supply, and food safety. At the same time, the number of University of California Cooperative Extension (UCCE) personnel declined resulting in a lack of expert advice. The University of California (UC), Davis detected the need and high pressure for UCCE resources and online education focused on young and beginning farmers; thus, proposed to create an educational program to attract, train, and prepare beginning farmers to those upcoming challenges. The initial purpose of the project was to train California's young and beginning farmers in sustainable fruit production on topics such as principles of tree biology, commodity production, fruit safety, technology tools, environmental conservation, fruit maturity, and harvesting techniques in both English and Spanish.

The project goal was to educate beginning growers in improving orchard management practices and postharvest-food safety, and responding to changing environmental conditions. The online educational program could be used to support beginning farmers' current and future performance in competitive markets. The creation and implementation of workforce commodity-production training programs with a foundation in tree biology as well as understanding why specific best management practices are used and why practices differ among tree fruit and nut crops could help maintain the technical skills required to keep the California specialty crop sector competitive for current and new workforces. By taking the online courses, beginning growers, but also more advanced growers, would be better able to critically evaluate the costs and benefits of different orchard management practices, and make the best choices based on their crop and orchard location to support California specialty crop sustainable production while protecting the environment.

This project built upon the 2010 Specialty Crop Block Grant Program Project 12: *Developing Internet Resources for California Specialty Crops.* Through the course of this project, the Fruit and Nut Research and Information Center (FNRIC) established peer-reviewed, updated online fruit and nut resources, and created a well-attended pomology short course, "Principles of Fruit and Nut Tree Growth, Cropping and Management." The 2010 project focused on making historical educational materials from UC Davis available on publicly accessible websites (the FNRIC main website and other associated websites) and assessed public interest in online educational materials. This project also developed new crop-specific webpages, and launched the first-ever "Principles of Fruit and Nut Tree Growth, Cropping and Management" extension short course. The current project builds upon the strengths and successes of that previous project to develop a certificate online training program that will benefit the California specialty crop industry. For this current project, information from the FNRIC's updated website, new UC Agriculture and Natural Resources pomology publications were

complemented with a series of hands-on short courses organized to create multimedia content. This included videos, images, and learning tools that formed the online educational program.

Project Approach

The FNRIC staff and advisory committee discussed and decided on the course modules, topics, syllabi, activities and content to develop to create the online educational pomology courses.

English and Spanish version of the following courses were completed:

- Pistachio course: “Advances in Pistachio Production” and “Avances en la producción de pistachio”
- Stone Fruit course: “Advances in Stone Fruit Production” and “Avances en la producción de fruta de hueso”
- Harvest and Postharvest course: “Harvest and Postharvest Management of Fruits and Nuts” and “Manejo de la cosecha y postcosecha de frutas y frutos secos”
- Walnut course: “Advances in Walnut Production” and “Avances en la producción de nuez”
- Almond course: “Advances in Almond Production” and “Avances en la producción de almendra”

The project team prepared well detailed scripts and power point slides (PPT) for each module and section based on each existing UCCE crop production manual and additional materials. These scripts were reviewed by experts (UC Davis Faculty, UCCE Specialists and Farm advisors) in each field, while pictures were collected and/or taken for video production. The scripts and PPTs were also all translated to Spanish.

Once corrected, the English and Spanish scripts were edited and sent to a professional voice recording company for audio recording. The project team decided to go with an external company after realizing that the ‘in house’ recordings were not of sufficient quality.

The videos were created using video editor software. For the English Pistachio online course, preliminary versions of the video presentations were rendered. These presentations were reviewed by the small group of experts. Feedback received indicated that the video presentations were too long and monotonous. Consequently, the project team enhanced the video presentations of all eight courses with more photographs, videos, and edited down the original videos into pieces of around five minutes each.

Supplemental information (reading material, videos and other useful tools), engagement activities (quiz or specific exercise), and entrance and exit tests were also prepared for each module and section of these courses. An entrance/demographic survey and a final evaluation survey were also developed, both in English and Spanish, to measure the outcomes of the courses. The materials created were uploaded to the UC Davis Canvas platform (UC Davis online educational platform).

Instead of collecting all material into one book, commodity specific scripts were edited and saved as pdfs. They were uploaded with each corresponding video on the Canvas platform, to help the students in their understanding of the videos.

For the Spanish Pistachio online course, a glossary of Spanish Agricultural Terms was created to help Spanish farmers become familiar with specific terms and to provide uniformity to their meaning. This was done, because of the diversity of the country origins of Spanish speaking farmers.

The English and Spanish Almond courses, were also completed within the project duration. Scripts and PPT slides were prepared for each module and section based on the *Almond Production Manual* and additional materials. The scripts and PPTs were translated to Spanish. Once corrected, the English and Spanish scripts were edited and sent to the contractor for audio recording. The videos were created using video editor software. The videos were uploaded to the Canvas platform, along with the entrance/demographic survey, the final evaluation survey, and the scripts provided in pdf format for each video.

The Pistachio, Stone Fruits and Postharvest courses, in English and Spanish, were offered to 200 Californian growers among people whom either took or were interested in the "hands on" classroom UCCE course "Principles of Fruit and Nut Tree Growth, Cropping and Management" in the past. The courses were also advertised and offered to a few extra test groups within the project team's network, the potential students were invited by email. The courses were set up and the interested growers were registered to the course on the UC Davis Canvas platform. The project team interacted with the students and solved technical issues when needed. A certificate of completion was sent to the first few students whom completed one of the courses. Data and feedback were collected from student's registration, participation and progression on the first six courses that were launched. Data was also gathered from the first completed demographic and evaluation surveys.

This project did not enhance the competitiveness of non-specialty crops. All project expenditures were tracked to ensure that grant funds were used solely to enhance the competitiveness of specialty crops.

The FNRIC advisory committee played an integral role in project development and execution by providing their expertise and critical review of course content and execution. The scripts of most of the courses were reviewed by a project partner expert in the field, either UC Davis Faculty, UCCE Specialists or UCCE Farm Advisors. Project partners also contributed to the PPTs and educational pictures used for creating the videos.

Goals and Outcomes Achieved

The project's main goal was to attract, train and increase the knowledge of beginning growers and demonstrate long-term changes in the use of this new knowledge and the impact on their specialty crop production operations. To evaluate the progress made toward achieving this goal and the Expected Measurable Outcomes, the following had to be determined:

- Number of beginning and transitioning growers whom took and successfully complete each course.
- Student's effort, understanding, progress and gain in knowledge with the courses.
- Student's change in current practices as a result of the knowledge gained in the online educational program.

The following was conducted to measure these outcomes in the short-term:

- As a requirement to register for a course, each student must answer seven questions in the entrance demographic survey.
- After completing the entrance demographic survey and before navigating the course, students answered questions in an entrance test, to establish their degree of knowledge in the subject.
- At the end of each section, the students answered a test question as a follow-up and review of the knowledge gained. Overall, the students had to answer at least 10 test questions.

- At the end of the course, the student had to complete a final evaluation survey, divided into a demographic component, a course evaluation component, and a student performance evaluation component, with a total of 30 questions.

The first six courses were offered to 200 Californian inhabitants among people whom either had taken or were interested in the classroom extension course "Principles of Fruit and Nut Tree Growth, Cropping and Management" in the past. Many of them were beginner growers or people working in the California fruit and nut industry. Table 1 below presents the number of people whom were interested in taking one or several of the six courses among the 200 people contacted.

Table 1. Participation in Online educational program "Establishing Online Nuts and Tree Fruit Education Program to Train California Specialty Crop Growers" as of June 2018

	Pistachio English	Stone Fruits English	Harvest and Postharvest English	Pistachio Spanish	Stone Fruits Spanish	Harvest and Postharvest Spanish	Total
# People interested and invited	57	60	58	60	60	60	355
# Students enrolled	14	28	31	4	6	7	90
# Enrollees who spent time in the class	7	26	22	3	3	3	64
Average time spent in the class	53:00:47	3:09:42	3:45:32	13:58:42	1:55:40	1:49:02	/
# Entrance demographic survey completed	5	20	18	3	1	3	50
# Entrance test completed	5	14	18	3	1	3	43
# Finale Evaluation survey completed	3	4	1	1	1	2	12
# Students who completed the course	3	4	1	1	1	2	12

The plan for the long-term outcome measures after the courses had been widely advertised, was to make a list of beginning growers participating in the course and whom would be willing to participate in a long-term evaluation program. For these growers, the project team would conduct follow-up surveys to assess their application of best practices after taking the courses. This would allow the project team to continue evaluating the concrete impact of the online educational program on specialty crops production by new California growers. No progress had been made towards completing this yet, as the team had experienced a delay in completing and releasing the courses.

There were approximately 60 persons interested in each of the online courses. Although to date, 4 to 31 students enrolled in the courses and only 3 to 26 were actively taking the courses (Table 1). The most popular courses were "Advances in Stone Fruits" and "Harvest and Postharvest Management of Fruits and Nuts."

A total of 50 students completed the entrance demographic survey. Among them, 33 were growers or farm managers, 23 students farmed or worked with less than 50 acres. Lastly, 19 students farmed or worked in the agriculture field for less than five years. The students worked with a diverse array of crops, from stone fruits, almonds, pistachios and walnuts. Less popular crops such as avocados, apples, pears, pomegranate,

blueberries, citrus, cherries, olive, table grapes, figs, etc. were also included. These results showed that the course was attractive to beginner growers but also to others starting in the fruit and nut industry.

The results obtained with the entrance test in the last work period with the first sample of students actively taking the courses are shown in Table 2. Between one and 17 students took the entrance test per course. The average score for each course varied from 44 to 75 percent showing that there was room for improvement and knowledge gain in the first test group.

Table 2. Entrance test results of the online educational program "Establishing Online Nuts and Tree Fruit Education Program to Train California Specialty Crop Growers" as of June 2018

	Pistachio English	Stone Fruits English	Harvest and Postharvest English	Pistachio Spanish	Stone Fruits Spanish	Harvest and Postharvest Spanish
# Entrance test completed	5	16	17	3	1	3
# Questions in Entrance test	16	14	9	16	14	9
Average score	44%	75%	64%	47%	64%	61%

To date, it was too early to review the results of the exit test questions, as only a few students completed each course for the time being (Table 1). Additionally, a technical issue with these questions was experienced at each end of section. The plan was to make them mandatory for the students to continue navigating the course, but it was realized that this was set up in in the UC Davis Canvas platform. As a result, not all students whom completed the course answered all exit test questions throughout the course. These exit questions, in comparison with the entrance test scores, will allow the project team to evaluate the progress and knowledge gain of the beginner growers as soon as more students have completed the courses.

The final evaluation survey was divided into a demographic component, which provided the same information as the entrance demographic survey but more complete, a course evaluation component and a student performance evaluation component. As of June 2018, 10 students finished one of the courses and completed the final evaluation survey.

The course evaluation component provided feedback on the course content and organization. All 10 students that completed one of the courses gave positive feedback (strongly agree/excellent and agree/very good) to all questions concerning clarity of the courses, organization, and ease of navigation. Videos, photographs and supplemental information quality, voice and narration quality, and video pace. Less positive feedback was received on the quality of the quizzes and the difficulty level: four students found the courses too simple. This was something that could be improved upon in the future. The student performance evaluation component of the survey, composed of three questions, allowed the project team to evaluate how many hours and how much effort each student put in while taking the course, in complement to Canvas statistics. All but two students were satisfied with their efforts in the course, the other two wishing they had studied harder. However, all students found the overall content of the courses excellent or very good and for all of them the course content covered what they expected. They would all recommend the courses to other students (six strongly agreed and four agreed).

The course evaluation component of the final evaluation survey included four questions directly related to the knowledge gain experienced by the student (Table 3):

- Question 1: Having completed the course I feel knowledgeable in the subject (strongly agree to strongly disagree).
- Question 2: The knowledge I acquired during the course will be useful in my work situation (strongly agree to strongly disagree).
- Question 3: This course will make a difference in the way I do my job (strongly agree to strongly disagree).
- Question 4: What is the main reason you took the course?

Table 3. The results obtained for the first three questions in the course evaluation component

Having completed the course I feel knowledgeable in the subject	The knowledge I acquired during the course will be useful in my work situation	This course will make a difference in the way I do my job
2 Strongly Agree	3 Strongly Agree	3 Strongly Agree
7 Agree	7 Agree	4 Agree
1 Neutral	-	3 Neutral

For question four: seven students answered that they wanted to improve their knowledge on the specific crop farming process; one wanted to refresh their knowledge on the subject; and the other two did not answer this optional question.

These results were very encouraging as not only the students were satisfied with the overall content of the course and would recommend them to others, but they also felt like taking the course increased their knowledge and would make a difference in their work situation, which was the main goal.

Beneficiaries

In the long term, the online pomology educational courses produced in the frame of this project will benefit mostly California's young and beginning fruit and nut trees farmers, working with stone fruits, walnuts, pistachios and almonds. However, the online course will also be useful for transitioning farmers, or farmers, and farm advisors. These courses will also prove useful to people already working in the fruit and nut industry, whom are wanting to improve their basic knowledge of tree biology, sustainable fruit and nut production, technology tools for fruit and nut production, and fruit and nut safety and postharvest handling. The project team expected to have the same public interested by the online courses as by the annual UCCE "Principles of Fruit and Nut Tree Growth, Cropping and Management", which has filled up rapidly every year since 2013.

As for now, the number of beneficiaries affected by the project's accomplishments corresponded directly to the number of students whom started and/or completed the different online courses produced in the frame of this project (90 students).

The UCCE courses were offered on an annual basis. The project team detected a high demand for UCCE courses and education for young and beginning farmers that could not be met only by in-class extension

courses. Thus, the online educational program was developed in the frame of this project to allow coping with the high demand for training from California's farmers and other interested groups. California's total value of all fruits and nuts in 2015 was $18.1 billion, nearly 67 percent of the total United States value of all fruits and nuts. Training growers, especially new growers, in fruit and nut production to ensure a high-quality production and high yield will be essential to sustain this important industry. Providing guidelines to reduce environmental impacts, improve food safety and insure a sustainable production will have a positive impact on the economic and environmental sustainability of this industry. This project will support the ability of California's producers, and particularly beginner farmers, and their associated marketing industries, to successfully increase competitive domestic and export markets. The primary economic impact would be increased productivity and profitability of the currently farmed acres for fruits and nuts, and more particularly here, for almond, pistachio, walnut and stone fruits production.

Lessons Learned

The main lesson learned was that creating educational videos was strenuous and very time-consuming at every step of the process: collecting up-to-date content material (appropriate illustrative pictures and reliable information sources in pomology), writing scripts, waiting for volunteer reviewers to review the material (scripts and PPT slides with pictures and graphs) to make sure the content was scientifically correct. As well as producing and editing the videos themselves. Additional professionals and students from different backgrounds and expertise were hired to aid in each of the afore mentioned steps. Over the span of this project, total of 110 videos were produced, of five minutes average length, for the five English courses. These were translated into Spanish for a total of 220 videos. Although translating videos was faster than making the videos from scratch, it was still time-consuming as all the material (scripts, slides and audio) also had to be translated. Producing that many videos proved to be an enormous undertaking, especially since the project team had no previous experience in educational video production. Additionally, several adjustments had to be made resulting from this lack of former experience. After a small expert group reviewed a preliminary version of the English Pistachio online course and found the videos too long and monotonous, the project team had to shorten the videos and enhance them with more photos. Dissatisfaction with the voice-over quality led to the decision to outsource audio production to an external agency for more consistency and professionalism, which was not in the original plan. This transition additionally delayed the overall progress. The project team also decided to develop the English and Spanish versions of the courses simultaneously, instead of taking care of the Spanish versions later, because it was found to be a more efficient and coherent work progression.

Overall, the amount of time and staff expertise necessary to complete the project in the initial proposal was underestimated. This unfortunately caused delays, causing a need to catch up in the last phase of the project. The team also learned the importance of a steady and very organized work progression to complete such a tremendous project. It is suggested that others wishing to create such an online educational program including videos, to not underestimate the time and staff-expertise necessary to collect and review materials and create high-quality, professional and up-to-date videos. A good option would be to take the time to progress one course/module at a time. Otherwise, progressing simultaneously at different development steps of different courses requires a high level of organization from a solid project leader and support personnel with different skills.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 30	**Project Title:** Sacramento Valley Beginning Farmer Apprenticeship Program	
Grant Recipient: Soil Born Farms	**Grant Agreement No.:** SCB15030	**Date Submitted:** December 2018
Recipient Contact: Shawn Harrison	**Telephone:** (916) 718-3563	**Email:** sharrison@soilborn.org

Project Summary

The United States Department of Agriculture (USDA), Economic Research Service found that "exit rates" for United States farms are 9 to 10 percent per year, with rates "substantially higher for recent entries than for older, more established farms." The objective of this project was to prepare beginning farmers for the unique challenges of small-scale specialty crop farming, mitigating the trials of farm start up and reducing failure rates for first generation farmers. The project also served the purpose of creating a legal means for farms to host apprentices. For the past three years, Soil Born Farms (SBF) and Center for Land Based Learning (CLBL) have each held an experiential beginning farmer training program which lasted seven to eight months. The SBF Urban Farmer Training Program emphasizes intensive urban agriculture and full-time farm work, while CLBL's California Farm Academy enrolls working adults who need business and production training to become farm entrepreneurs. Experience from these programs has shown that multiple years of education and a strong component of on-farm training are needed in order for trainees to move successfully into independent farm operation and management. Evaluation of the SBF and CLBL programs has indicated that while participants are highly satisfied with their first year of training, once students start farming they encounter a wide range of obstacles that can become crises from which they cannot recover. The Sacramento Valley Beginning Farmer Apprenticeship Program developed and introduced a multi-year educational model that blended intensive coursework with on-farm mentoring in order to combat the issue of new farmer attrition. This project which was led by SBF in partnership with CLBL

This project built upon the 2011 Specialty Crop Block Grant Program Project 62: *Urban Farmer Training Program*. A key lesson from the previous project was that one year of instruction does not provide adequate preparation for students to develop a successful farming business or obtain management-level employment. The Sacramento Valley Beginning Farmer Apprenticeship Program builds on and deepens the earlier training program models by providing multiple years of advanced level work experience, instruction, and technical assistance for a broad cross section of beginning farmers. The current project is a new, collaborative approach to advanced-level farmer training, drawing on the expertise of regional organizations and farm businesses.

Project Approach

Partner Planning and Apprentice Committee Meetings: On-going partner meetings were scheduled each month with attendance from SBF, CLBL, Department of Apprenticeship Standards (DAS), and host farmer mentors. During the last year of this project, the Local Education Agency (LEA) partners also attended this meeting periodically. These include Los Rios Community College and San Joaquin Office of Education. This group comprises the Apprenticeship Committee tasked with program development, reviewing apprentice applications, monitoring apprentice learning objectives and handling apprentice disputes/disciplinary actions. Other smaller planning meetings were also held regularly between SBF and CLBL as well as internally with program training staff.

Align and Formalize Training Program Content: Completed and all beginning farmers now participate in classes. Comprehensive list now includes a list of over 70 classes each year and over 200 hours of coursework. Includes development of strong business and farm management focus instruction.

Run First Year Training Programs: Formally merged SBF's program into CLBL's Farm Academy curriculum component along with other participating mentor farms. This classroom instruction occurs at CLBL headquarters with a cohort of 20 to 30 first year farmers each year. All on-farm training and field trips with beginning farmers occurs at CLBL, SBF and other participating farm sites.

Develop 2nd and 3rd Year Training Program Components: An assortment of 27 supplementary workshops and classes have been developed and offered to the 2nd and 3rd year apprentices based on their individual learning objectives over a two-year cycle. This complements hands-on training at host farm and incubator training sites (sites offered by CLBL and SBF where beginning farmer produces crops under their own label).

Recruit and Train Five to Seven Farm Apprentice Hosts (Farmer Mentors): Provided training to five farmer mentors including SBF, Full Belly Farms, Rominger Brothers Farm, Muddy Boot and Say Hay. Four of these farm mentors (excluding Say Hay) will be taking on an apprentice in the 2018 production year.

Recruit and Place 2nd and 3rd Year Beginning Farmers: From October 2015 to September 2016, ten 2nd year apprentices were placed at host sites and/or incubation training sites. From October 2016 to September 2017, seven 2nd year apprentices and seven 3rd year apprentices were placed at host sites. From October 2017 to December 2017, three 2nd year apprentices and ten 3rd year apprentices were placed at host sites.

Facilitate Information Sharing Among Beginning Farmer Cohorts: Hosted informal peer to peer sharing sessions once every two months. New Farmers Guild program also emerged during the project period that assisted with network building among beginning farmers.

Support Business Planning Development and On-going Technical Assistance for 2nd and 3rd Year Beginning Farmers: CLBL staff met with project partners to develop a formalized partnership with California Farmlink, Kitchen Table Advisors, and other business partners to provide on-going business planning technical assistance and loan assistance for advanced level beginning farmers to help them navigate business operation in their early years. Complemented by business development classes taught during first year of training as well as on-going staff initiated business planning mentoring during bi-monthly one-on-one check-ins.

Develop a Formalized and Accredited Apprenticeship Training Program with Approval from DAS: A second LEA through San Joaquin Office of Education was brought on to support the training program and act as a fiscal sponsor on future funding opportunities. Training standards are complete and approved by San Joaquin and Los Rios College District. Accreditation of the program by DAS was approved in January 2018.

Secure Workforce Funds to Assist in Covering Apprentice Wages: Three meetings were held with Sacramento Employment and Training Agency (SETA: local workforce investment bureau) to plan for workforce fund eligibility. Funding for continued program management in 2018 was secured through partner at San Joaquin Office of Education.

Run Pilot Accredited Apprenticeship Program with Three to Five Hosts and Three to Five Apprentices: Six hosts (mentor farmers) were matched with eight total apprentices.

Evaluate Accredited Apprenticeship: All evaluation materials for the program were developed. This includes: Registration and/or Application forms; Pre- and post-apprentice assessments; Attendance log; Field hours log; Technical Assistance log; Mentor survey; Participant follow-up survey and interviews; Interview protocols (program staff, farmer mentors, program participants). Beginning farmers were monitored monthly and evaluation tools were administered to a subset of participants in the 2017 year.

Disseminate Evaluation Results: Program updates were shared at the January 2017 and 2018 Ecological Farming Conference. Additionally, the program was presented at the 2017 National Incubator Farm Training Institutes field day and the Community Food Projects – Apprenticeship Learning Network in Boston, MA.

Prospective trainees were pre-screened through an application process to ensure they understood and agreed to the project's sole focus on specialty crop production. All training opportunities on partnering farms were planned to ensure that field days, workshops, and apprenticeship placements addressed only specialty crop production. Partnering farms agreed to these parameters in a written statement. Staff and contractor hours were monitored through the use of detailed timesheets that clearly indicated employees' area of work and the associated funding source.

SBF acted as the project lead, providing overall project management including contractor oversight, work plan monitoring and financial tracking. Program management, program development, evaluation oversight, program accreditation were conducted in partnership with CLBL. Project results were disseminated by CLBL. Evaluation tools and subsequent assessments were conducted by a consulting firm.

Goals and Outcomes Achieved

Increasing the population and success rate of beginning farmers in the Sacramento Region has always been the overall goal. Key activities related to this goal include:

- Program partners created a regionally focused and centralized farmer training program that leverages the skills and resources of non-profit and for-profit industry partners. The two central partners, SBF and CLBL, formally merged their programs under the California Farm Academy name which now includes three interrelated training tracks including Beginning Farmer Training Program, Apprenticeship and Business Incubator. These increasingly more intensive training tracks allow for a natural progression of skills and knowledge development as beginning farmers move from practice to production. A key component is the blend of rigorous classroom instruction with intensive field practice to build proficiency in core farm management skills areas.
- A key component of this outcome was developing the accredited Apprenticeship program in order to create a legal pathway for beginning farmers to train on existing farms where hands-on learning is most powerful and real. Now approved through the DAS, the Apprenticeship program component is the only active accredited apprenticeship in California. The primary program requirements of the apprenticeship include 3,000 field hours on host farm sites and over 250 hours of classroom instruction.
- Real world training at existing specialty crop farms (mentor farmers/host sites) is an integral component of the program model. Over the project period, program staff created an expanding network of specialty crop farmers to provide diverse training experiences for the apprentices as they move through two to three years of intensive training. Currently six farms have received a total of eight apprentices. Interest and

demand for the apprenticeship is rapidly growing from both host farms and beginning farmers. In the 2017-2018 application period 55 beginning farmers applied to the program and 10 farms expressed interest in receiving apprentices. As program capacity builds the number of farms and placements will build, creating an annual mix of 30 to 50 beginning farmers participating (combination of 1st, 2nd and 3rd year beginning farmers).

- In order to assess knowledge gain and success of beginning farmers in and exiting the program requires the development of comprehensive program evaluation tools. Program staff worked with the consulting firm to create a logic model for the training model and create monitoring tools for the project's primary activities and objectives. A report detailing these comprehensive tools was completed by the consulting firm. Significantly, of the program participants evaluated, 100 percent had verified gains in knowledge and skill by participating in the program and 77 percent of alumni remain in specialty crop production (with large percentage of remaining 23 percent expressing intent to secure a career in specialty crop production).

While not quantitative, the long-term outcome of this project was to reduce farmer attrition by creating a pathway into agriculture for beginning farmers that gives them the best chance of success in the industry. This outcome has definitely been impacted by the project's collaborative work. In the last round of apprenticeship placements, project staff witnessed increasing interest in the program with 55 applications and 10 farms interested in placing apprentices. With the training systems and methodology developed by the project, project staff expect these numbers will increase along with increasing success rates of beginning farmers.

The following is the list of outcomes accomplished during this project:
Goal #1: Eighty (80) to 90 beginning farmers trained
Result #1: Seventy-eight (78) beginning farmers trained (unduplicated); 103 beginning farmers trained (duplicated) accounting for 1st years transitioning to 2nd year and 3rd year of training.

Goal #2: Ten (10) to 15 2nd year farmers by December 2017
Result #2: Fourteen (14) 2nd year farmers by December 2017

Goal #3: Five to eight 3rd year farmers by December 2017
Result #3: Eleven (11) 3rd year farmers by December 2017

Goal #4: Ten (10) to 20 apprentices and other regional farmers offered support and technical assistance
Result #4: Twenty-seven (27) apprentices and farmers offered supported

Goal #5: Program accreditation through Department of Apprenticeship Standards
Result #5: Accomplished the program accreditation

Goal #6: Ten (10) Farms committed and three to five piloting accredited program
Result #6: Ten (10) Farms committed and six piloting accredited program

The project was successful in increasing the population and success rate of beginning specialty crop farmers as evidenced by:
- Seventy-eight (78) first year beginning farmers enrolled (unduplicated)
- Fourteen (14) 2nd year farmers enrolled, placed and trained

- Eleven (11) 3rd year farmers enrolled, placed, and trained
- One hundred (100) percent skills and knowledge gain among beginning farmers evaluated
- Seventy-seven (77) percent of Beginning Farmer alumni reported continuing employment in Specialty Crop agriculture

The project was also successful in increasing the number of accredited apprentices and training host sites (mentor farmers) as evidenced by:

- Four farms committed with three apprentices placed at two farms in 2017 and six apprentices (1st and 2nd years apprentices) at six farms in 2018. An additional six farms expressing interest for next round of applicants.
- Program staff succeeded in establishing accreditation from DAS. This program holds the only active accredited beginning farmer training program in the State of California.

Beneficiaries

The beginning farmer training program developed with this specialty crop project benefits three primary groups:

- Beginning Farmers: An assortment of beginning farmers benefited from this program through direct training and on-going technical assistance. These farmers' success rates have been enhanced as they work to develop and grow their farming businesses, increase production and serve more customers with specialty crops.
- Existing Specialty Crop Farmers: Over the last two years an expanding pool of trained farming apprentices are entering the California labor stream, providing existing farms with higher skilled labor.
- Specialty Crop Consumers: As beginning farmers enter the California job market and start their own farm as an owner/operator, more high value specialty crops will be available for sale and consumption.

Over the project term 11 beginning farmers began selling specialty crops for market for an estimated total local market sales value of $128,000. The outlets included local restaurants, grocers, school district, independent farm stands, Community Supported Agriculture (CSA), food pantries, florists, restaurants and private events. Details were as follows:

- All 11 farmers sold to Local Restaurants.
- There were 10 farmers who sold through a farmers Market.
- There were three farmers who operated an independent farm stand.
- Two farms ran a CSA food box program.
- Two farmers had sales for weddings and other private events.
- Two farmers offered on-farm u-pick.
- One farmer sold to a food pantry program.
- Four farmers sold to an aggregate CSA program.
- Two farmers sold to grocery stores.
- Two farmers sold to a local florist.
- One farmer sold to local school district.

Lessons Learned

The deeper the project staff progressed into the beginning farmer training program, the more conviction they had gained for the need for this type of program. On the positive side project staff have clearly observed that

the blend of real hands-on training at host farms combined with classroom instruction is leading to greater skills and knowledge development. Project staff also saw that the blend of training tracks that were developed works well to attract a diverse applicant pool. For those that cannot make an immediate full-time training commitment the basic California Farm Academy fits best, while the Apprenticeship and Business Incubator appeals to those that are looking for full immersion. In all scenarios, the partnership and collaboration between complementary non-profits and for-profit farms has created a very strong program approach that provides for the greatest long-term success. The Sacramento region now has a centrally organized and collaborative structure that will enable a large number of beginning farmers to move through and receive consistent training in the critical farming skills. It also provides for a legal training structure that allows for more host farms to participate in the program. Additionally, the accreditation route allows the training program to access funds from workforce funding, potentially helping with program management costs and wage assistance for host farms.

The accreditation component has been a major learning point for project partners. Partners grossly underestimated the complexity of California farm labor law (versus other industries) and the time and effort it would take to attain accreditation. Project staff also found that as one of the first programs like this in the state, they were left to work through challenges that did not have a clear pathway to solve them. Federal, state and interstate agencies often had different answers or approaches to key questions that the project needed to solve. Many of these conversations were tracked in chart form so that project staff could demonstrate the complexity to various legislators that the project turned to for support. Similarly, this analysis should assist in generating needed reform and guidance in the event that other groups in the state choose to pursue accreditation models.

While not entirely unexpected, project staff saw an increase in the regional dialogue about the importance of workforce development for the agriculture industry as a result of the program. A genuine excitement was built around this program. Project staff have seen evidence of the emergence of a more dynamic and complete food and agriculture pathway, starting with K-12 early education, into college and into employment.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 31	**Project Title:** Beginner Farmer Entrepreneurial Intensive	
Grant Recipient: Community Alliance with Family Farmers	**Grant Agreement No.:** SC15031A	**Date Submitted:** December 2018
Recipient Contact: Evan Wiig	**Telephone:** (415) 710-5692	**Email:** evan@caff.org

Project Summary

With the average age of farmers here in California rising each year (today surpassing 60), project staff recognized the dire need to train a whole new generation of agricultural entrepreneurs, in particular those aspiring towards the specialty crop industry which is so central to California agriculture. However, throughout the organization's ongoing work with new, young and would-be farmers, project staff noticed that while practical on-farm skills can be easily obtained through internships, on-the-job experience or even trial-and-error via their first farming enterprise, practical business skills are harder to come by. Aspirants rarely get into farming with their focus on record-keeping or marketing. And just as rare are farm employers who spend as much time teaching their interns or employees vital office-based skills as they do field-based skills. Many farm training programs gloss over these essential skills, likewise focusing more on field work. Meanwhile more general business classes and education programs catered to new entrepreneurs often fail to account for the unique challenges and circumstances of starting a specialty crop enterprise.

Community Alliance with Family Farmers (CAFF) has worked with farmers for over forty years, and project staff have seen many farms start and close. And among those, far too many new farms closed within just the first couple of years. However, as seen so far, almost never do those farms close because of crop failure or because of any field-related problems. Almost always, it's been because of the many circumstances surrounding the field work that could have been prevented with proper business planning. Failures typically happened because a farm hasn't managed cash-flow or finances, because they can't find or secure appropriate markets, because they lose their lease mid-season, etc. Therefore, the challenge facing new farmers isn't one of purely farming, but of a lack of business skills and entrepreneurial savvy.

The Beginner Farmer Entrepreneurial Intensives were designed to address the above issues directly by providing a series of trainings that focus solely on the business side of farming. In the past decade, project staff have seen a resurgence in the number of young people attracted to the prospects of farming and, to meet that demand, a resurgence in new farming training programs and farms offering internships. But while many of these programs and opportunities for on-the-job experience are vital to the development of a new farmer, if these starting entrepreneurs start out on their own without a solid grasp of sales, regulations, record-keeping, and marketing, it's unlikely that they will succeed.

The intention of this program was not to replace these newer training programs, more traditional agricultural colleges or on-the-job training, but rather to supplement them. The project staff intended to design a program that would be accessible and flexible enough for anyone getting started in farming to incorporate it into their existing work and life—whether that be a current student, farm intern or employee, or even a new agricultural entrepreneur in their first few years of production. These winter-based intensives offered a crash-course for those newer to farming and a necessary re-fresher for those struggling through the first few years, so overwhelmed by the day-to-day challenges of managing a farm that they often overlook the longer-term needs

of their operation such as developing markets, investing their time and resources smartly, and simply planning ahead with proper records so they can accurately assess the strengths and shortcomings of their operation.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Over the course of the grant period, project staff successfully developed a new educational program designed to address the issues laid out above, targeted specifically to those either preparing to start their own specialty crop farm or those in their first few years of production. Working closely with partner organizations and other educators, as well as with farmers both new to the trade and seasoned, project staff determined the needs of new farmers and the gaps in existing training programs. The result was a series of entrepreneurial workshops focused on the following topics: business planning, record-keeping, land access and lease management, finances, sales, marketing, rules and regulations.

Next, project staff developed and carried out an outreach strategy to market this program to the right audience, identifying 10 counties spread throughout the state where demand was highest for such a program. Selected were: Yolo, Sonoma, San Diego, Humboldt, Nevada, San Luis Obispo, Monterrey, Mendocino, Alameda and Marin. In each of these communities, project staff relied on existing partnerships or cultivated new relationships with local farm resources to help select local presenters, secure venues, promote and cater each specific intensive to the unique particularities of that region—recognizing that the circumstances, from climate to market, vary widely between places as diverse as Humboldt and Alameda. While the structure and outline of each program remained constant, project staff worked to hone the specifics of each workshop to that particular region by speaking with local farmers and farm support organizations and by contracting with seasoned farmers and farm business experts within each community.

Overall, 10 successful programs were hosted with full classes and knowledgeable presenters. In several of these regions, project staff partnered with other educational programs to provide the intensive as a supplement to their students or alumni and in other places; project staff incorporated the intensive into an existing program or farm conference, such as the Sustainable Food & Farm Conference in Nevada County, the SoCal Farmers Summit in San Diego and the EcoFarm Conference in Monterrey County. This allowed this program to reach even more students as well as to connect students to additional resources already available in their community.

Project staff held a career fair in March 2018, an event called Careers in Agriculture, hosted at the University of California, Davis (UC Davis) and in partnership with several farming-related departments and other ag-specific partners. CAFF project staff offered attendees a chance to meet with several employers, ag professionals and other farm educational opportunities. Not only did new farmers get to meet potential employers and service providers, but there was also a big focus on passing down experience and wisdom from those who've been in the field for a long time. Attendees got to hear how established farmers and other ag-related professionals entered the field, what they learned, what worked, what didn't work, and fielded questions from the many attendees, which included students, interns, farm employees and new farmers.

All programs were specifically catered to specialty crop producers and the marketing made very clear that the education provided would cover issues related to specialty crop production. All farmer-presenters were specialty crop producers and other presenters were experts in support of specialty crop producers. The

program was designed and marketed to be applied to the unique challenges and opportunities inherent in specialty crop production. This project did not benefit non-specialty crops.

Over the course of this project, project staff worked closely with several partners, whether to help promote, to lead specific workshops, to host the series at a larger event, etc. These partnerships were vital to reaching the target audience in these ten different regions and to bringing regionally-appropriate expertise and resources to these students.

Goals and Outcomes Achieved

Activities to achieve project goals included the development of a robust, well-researched curriculum based on comprehensive farmer feedback, comparable programs and close work alongside partners and other ag support experts to identify needs, gaps, essential skills, etc.

Next was the creation of an outreach plan and promotions, branding the program to best attract the target audience of new and young farmers entering the specialty crop industry. These efforts included the creation of webpages, social media, graphics, fliers and connecting with partner organizations as well as attending and tabling at several events at which the target audience would be present.

For each program, project staff secured venues, materials and all the other necessary logistics to host these workshops. And for each, project staff sought and contracted the best local experts, whether farmers, local food business leaders or technical assistance providers, to present on each topic. The project staff worked closely with each presenter to craft their take on the topic, providing templates and coaching in varying degrees, to focus their presentations on the target audience and program goals. The project staff then created materials, both printed for attendee packets during class, as well as digital for preparation before the workshop series and follow-up homework and additional resources for after the workshops.

For the Careers in Ag event, a year was spent planning and promoting the event at UC Davis, working with several partners and providing programing that would attract would-be farmers from across California. The project staff outreached to farm business employers, professional service providers, educational programs and farm owners to attend, present, table and provide as much information and advice to attendees as possible.

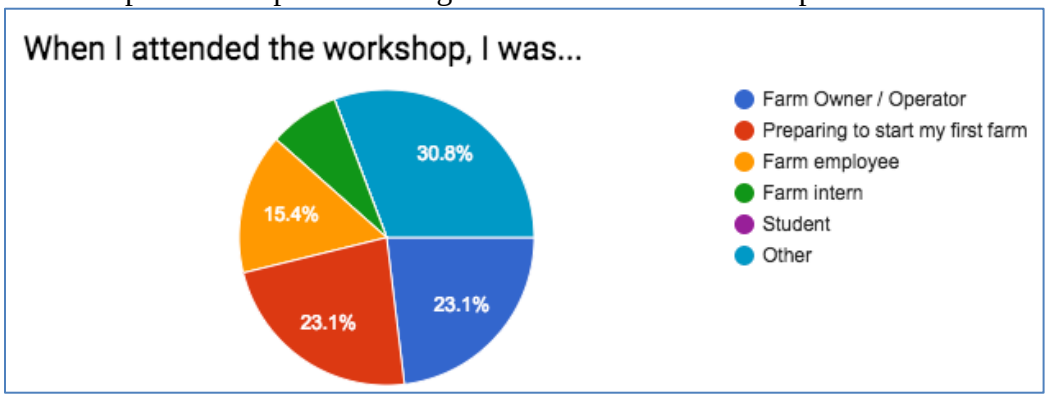
In addition to immediate post-workshop evaluations, project staff also sent out a final evaluation survey to all past attendees of the programs, to gauge the progress they've made toward their stated goals since last seeing them and how the program helped them achieve this. In some cases, students had only just finished the program a few months ago and even those who attended the earliest workshops have only had a couple years, so the measurement was not entirely "long-term," but it did show how this program has helped in their first few steps, whether that be seeking out the additional farm experience they need before starting their own operation or simply tightening up their existing operation to incorporate the lessons learned during the intensive.

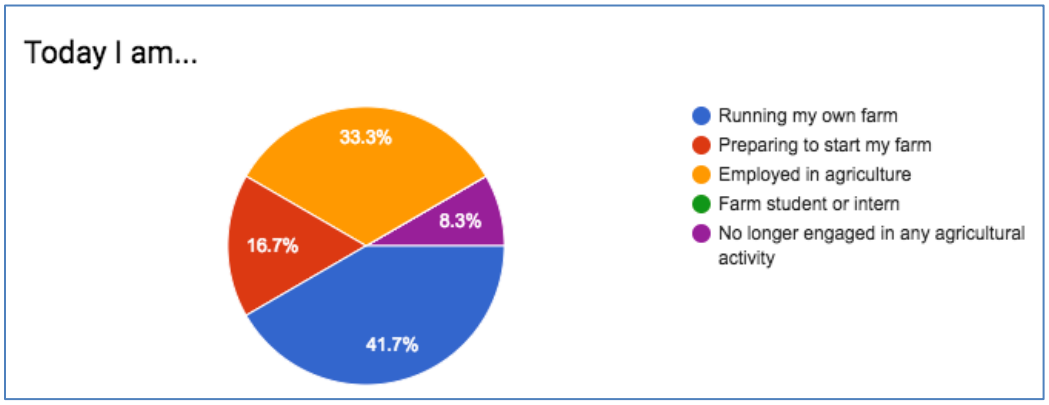
Below are graphs and charts showing the results of the final evaluation:

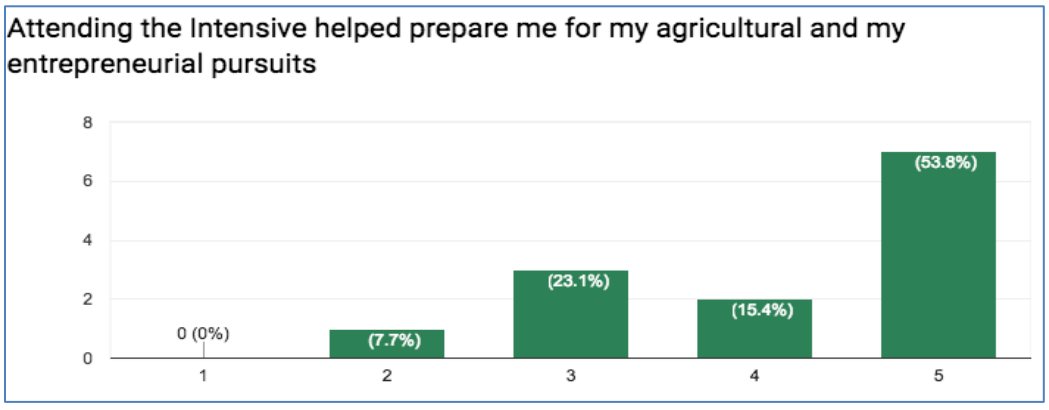
- All students who enrolled in the program completed the program--meeting the initial goal of 90% completion rate.
- When asked whether the program helped them feel more confident, knowledgeable and prepared to pursue their agricultural ambitions, 0 percent answered "None", 7.7 percent

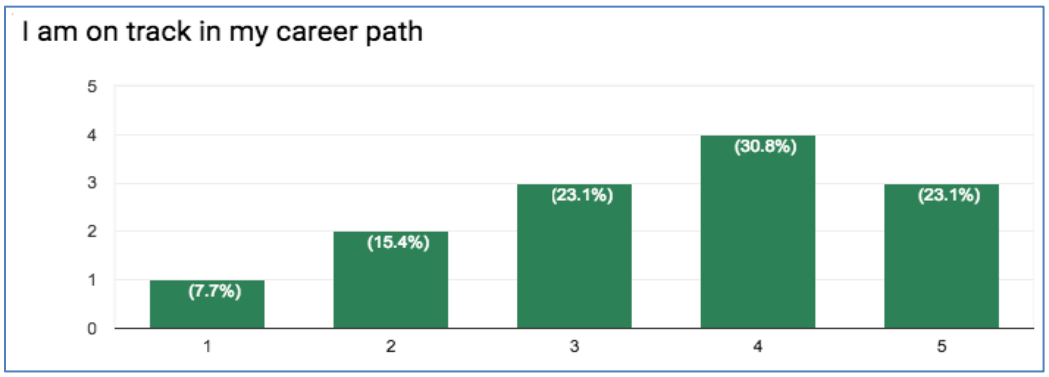
responded “Not much”, 23.1 percent answered “Somewhat”, 15.4 percent responded “Very Much” and 53.8 percent “Definitely” equaling a 92.3percent cumulative positive response, surpassing the initial 75 percent goal.

- While students began at a variety of levels, from student to farm owner, at the time of the final evaluation, 41.7 percent now run their own farm, 33.3 percent are employed in agriculture, 16.7 percent are preparing to start their own farm and only 8.3 percent are no longer engaged in agriculture.
- Over half of respondents answered “Very much” to whether this program helped prepare them for their agricultural pursuits, 15 percent responded “Yes”, 23.1 percent responded “Some”, 7.1 percent responded “Not Much” and 0 percent responded “No”
- Most respondents reported feeling “on track” for their career path









Goal: Host 10 workshops across California and one Career Fair
Accomplishment: Hosted 10 workshops across California and one Career Fair

Goal: 60 percent of attendees will be on track in their career goals by end of grant project.
Accomplishment: Only 8.3 percent of final evaluation respondents reported being no longer engaged in agriculture whereas the remaining 91.7 percent are either actively farming, preparing to start a farm or employed in agriculture

Goal: Train 200 new and aspiring specialty crop producers in business skills
Accomplishment: Trained over 270 new and aspiring specialty crop producers, with the majority reporting feeling on track and more confident in their agricultural ambitions

Beneficiaries

The beneficiaries are the 270 new and aspiring farmers who are now pursuing careers in agriculture and/or their own specialty crop business here in California. With the skills they gleaned from these workshops, the attendees have a firmer grasp on the business basics of starting and running a farm successfully. With each new successful farm, the beneficiaries ripple outward in each community: consumers with healthy new options at the farmers market, distributors and grocers who have increased supply and options, other local ag-related businesses who benefit from more demand for product, etc.

In addition, the many partners with whom CAFF worked benefited by being given a platform to share and promote their work. Attendees of the workshops who recognized they weren't ready to start a farm often sought further education through one of the partners with whom CAFF worked, while farmers who were ready or were already operating their own farm learned about the many resources in their community and across the state, including technical assistance from such organizations as FarmLink, their own Ag Dept, UC Cooperative Extension and many more. The outreach and mobilizing that project staff did for these many programs offered more exposure to these many great service providers, which was definitely a win-win.

One study indicated that nearly 32 jobs are created for every $1 million in revenue generated by produce farms involved in some form of direct marketing, compared to only 10.5 jobs for those involved in wholesale channels exclusively.

More local food options from the types of farms that the attendees are starting also boosts the retail, restaurant and tourism industries. Farm-to-table offerings, which many of the attendees would market to, provides a whole host of economic drivers in communities across California.

Specialty crop production, more than any other form of agriculture, requires the most labor, which means the more than the attendees succeed and scale-up, the more jobs will be available in their communities.

Lessons Learned

The more structure and guidance provided to workshop presenters, the better. While project staff do want to provide them with enough flexibility to accommodate their own style and the particularities of their region, the goals of the program must guide how that material is presented.

Plan far ahead: Laying out dates and locations far in advance allowed to spend time building relationships in each area, getting the word out and better learning how to apply the curriculum to that particular region's farmers.

Interactive materials work: Attendees responded very positively to the worksheets provided them and allowed them to apply the knowledge learned in the course to their unique farming operation, whether that was provided before, during or as a follow-up to the workshop series.

Group work: Attendees enjoyed bouncing ideas off one another, so the more project staff could include interactive, group sessions between presentations, the better. Plus, the solidarity and relationship-building between attendees proved valuable. Most students requested more time to network and get into smaller groups.

Be specific in marketing: By clearly outlining the program's objectives and aims, project staff were able to attract the right audience, which the classes appreciated—i.e. having peers who were serious and similar in their goals and somewhat similar in where they stood in their trajectory.

Winter workshops: Getting farmers to take off whole days during the growing season, even early Spring, proved a challenge. Speak to local service providers and other education programs before promoting. To avoid seeking opportunities to fill gaps rather than replicate efforts, it worked incredibly well to approach local groups and ask how a program like this could benefit the farmers in their area and even their own program and services.

The project staff created a well-organized online clearing-house for the many resources provided during the program, such as tip sheets, worksheets, recording keeping templates, etc.

The project allowed this organization to enter into regions of the state where project staff have been less active, building relationships with like-minded organizations. The project staff were able to compare notes with other education programs and, as a result of partnering, went back to refine the curriculums. And likewise, because project staff worked with several different partners in each region, and were also able to introduce organizations with each other, those that hadn't yet collaborated or helped make local groups aware of statewide resources that they can share with other farmers in their region.

Additional Information

The webpage for this program, including links to each regional program and its details, presenter list, etc, can be found at: http://www.farmersguild.org/entrepreneurial-intensives-2016-2018.html

For a link to the clearinghouse of program material, provided to students after attending: https://drive.google.com/drive/folders/0B4_Do1Zj78sLbWZlS2JWS2RZcW8

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 32	**Project Title:** Training the Next Generation of Leaders for the California Strawberry Industry	
Grant Recipient: Cal Poly Corporation	**Grant Agreement No.:** SCB15032	**Date Submitted:** December 2018
Recipient Contact: Gerald Holmes	**Telephone:** (805) 756-2120	**Email:** gjholmes@calpoly.edu

Project Summary

Agriculture faces many complex environmental, biological and social issues. The strawberry industry, in particular, is often the lightning rod for many of these issues given its high value, urban setting, susceptibility to pests and diseases and high manual labor inputs. One of the industry's greatest needs is an ongoing infusion of bright, young, educated people entering the industry to provide leadership for addressing current and future issues.

The purpose of this project was to train undergraduate students at Cal Poly San Luis Obispo for careers in the California strawberry industry and agriculture in general. Through work experience with a diverse group of organizations and individuals, students received the training necessary to complete their degrees well prepared for a career in the California strawberry industry. Examples of positions included: land preparation; labor management; pest management; pest control advising; applied field research; lab techniques in plant pathology and entomology; scheduling harvests, processing; sales; marketing; cold chain; postharvest handling; food safety; training and education programs, etc.

The importance of this project rests on the need for constant infusion of young talented individuals who will provide leadership in resolving current and future agricultural issues facing the strawberry industry. Current issues such as the phase-out of methyl bromide fumigation, increased regulation, pest resistance to pesticides, labor shortages, urban encroachment and environmental concerns all exert pressure on the California strawberry industry, and the future promises to deliver more challenges.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Activities undertaken during the entire grant period included:

Work experience opportunities identified:
Industry leaders were contacted to learn of internship opportunities for Cal Poly students each year during the winter months. These opportunities were presented to students during Cal Poly's Ag Showcase in mid-January each year.

Internship starter kit assembled:
The internship starter kit contained the following items: field bag, trowel, hand lens (14X and 20X) with lanyard, strawberry sickle knife, fine tip pruning shears, field hat, pocket knife, gloves, regular and fine tip sharpies, golf towel, sunscreen, books: UC-IPM Strawberries, 2nd edition; Compendium of Strawberry Diseases; Strawberries by J. Hancock. Most items were purchased with grant funds while others were donated by industry.

New course developed:
A new course (AEPS 470: Current Issues in the Strawberry Industry) was proposed and approved. Topics were selected after a student ranking of subject matter. Speakers for each topic were selected based on current expertise in the industry.

AEPS 470 - Spring 2016

Date	Topic	Speaker/Destination
March 30	From meristem to market: the process of growing strawberries in California	Vice President - Naturipe
April 13	Pest management issues in California strawberries	Research & Technical Director - Naturipe
April 23	Field scouting, bug vacuums, harvest machines, postharvest handling	Field trip to Santa Maria
April 27	Robotic harvesting and other novel technologies	Founder/CEO - Food Origins
May 11	Fumigation: past, present and future	Director of Research & Regulatory Affairs-TriCal, Inc.
May 21	Land preparation, soil fumigation, irrigation, processing, pest identification, disease diagnosis	Field trip to Santa Maria
May 25	Breeding strawberries: past, present and future	Retired Driscoll's strawberry breeder

AEPS 470 - Spring 2017

Date	Topic	Speaker/Destination
April 5	Strawberry production practices around the world	Retired Breeder Driscoll's
April 19	Arthropod management	Driscoll's Entomologist
April 22	Driscoll's strawberry breeding plots, conventional and organic production methods, bench top production system, postharvest handling	Field trip to Santa Maria
May 3	Organic and conventional production methods; challenges and opportunities	Partner & VP of Operations Andrew and Williamson Fresh Produce
May 17	Disease identification and management	Vice President, Agricultural Solutions
May 27	Harvest and harvest aids, processing strawberries for IQF, juice, etc.	Field trip to Santa Maria
May 31	Breeding strawberries: the process of developing cultivars	President Plant Sciences, Inc.
June 7	Postharvest considerations, clamshell packing exercise	Research Associate, Cal Poly Strawberry Center

AEPS 470 - Spring 2018

Date	Topic	Speaker/Destination
April 4	How strawberries are grown around the world	Owner & Executive VP of Cal Giant
April 18	Disease identification and management	Extension Plant Pathologist Professor Emeritus, UCD
May 2	Labor management and its impact on strawberry production	NorCal Harvesting
May 9	Current field and postharvest operations	Field trip to Santa Maria
May 16	Advances in automation technology	Manager of Production Automation from the California Strawberry Commission
May 30	Breeding strawberries: the process of developing cultivars	Research Associate – Strawberry Breeding Program & Dept of Plant Sciences, UC Davis
June 6	Postharvest considerations, clamshell packing exercise, review of course	Research Associate from the Cal Poly Strawberry Center

Interns placed:
According to the goals of the project, interns were placed in increasing numbers in each year: three in 2016, five in 2017, and 12 in 2018. Each intern received the internship starter kit and took the DiSC personality assessment and completed the AEPS 470 “Current Issues in the Strawberry Industry course.” Three students returned for a second or third year of internship, giving them greater experience and training for a career in the strawberry industry. Internships occurred with companies such as Naturipe, Helena Chemical, Driscoll’s, Jacobs Farm, Swanton Pacific Ranch and the Cal Poly Strawberry Center (CPSC).

Senior projects were also completed by the student interns. However, the senior projects were only applicable to interns who completed multiple years of the internship, including their final year. A total of four senior projects were completed. Senior project titles were; Evaluation of Cover Crops and Anaerobic Soil Disinfestation on Verticillium Wilt of Strawberry, Ability of EndoMaxx arbuscular mycorrhizal fungi (AMF) to colonize strawberry roots and its effect on yield and plant biomass, the Evaluation of Zivion 10SC for Crop Safety and efficacy against “box rot” when used as a bare-root plant dip prior to long term cold storage, and the Time-Motion Study of Strawberry Pickers and Analysis of Potential Time Savings.

This project did not enhance the competitiveness of non-specialty crops.

Project partners helped identify potential internships and, in some cases, offered internships. Naturipe, Driscoll’s, Smucker’s, Cal Pacific, Cal Giant, TriCal, Plant Sciences, NorCal Harvesting, UC Davis, California Strawberry Commission and Swanton Pacific Ranch all contributed to the project by hosting interns or speaking in the seminar series.

Goals and Outcomes Achieved

Each year, interns were recruited during Ag Showcase, a career fair for the College of Agriculture, Food & Environmental Sciences. Interns were placed with respective employers where they received on-the-job training in many different aspects of the strawberry industry. Interns received the internship starter kit which is a canvas tote filled with essential work tools and books to assist them in their jobs. The DiSC personality assessment was completed by each intern. This test measures a person's Dominance, Influence, Steadiness and Conscientiousness as it relates to the work environment. Interns were given Spanish language skill development support by making a library of study resources available, including AgAccess' "Spanish in the Field" and Command Spanish's "Occupational Spanish for Green Industries" books and practice CDs.
The CPSC Director visited each intern at their work site once during the summer to see first-hand the working environment, meet their supervisors and assess the quality of the experience for the intern and their supervisors. A total of 61 students completed the new course "Current Issues in the Strawberry Industry" (AEPS 470) in its first three offerings. In the course, students learned from industry experts about the most pressing problems facing the industry and interacted one-on-one with industry leaders.

A total of 21 internships were completed by 17 students (four students participated more than once). Of the 17 interns, six have graduated. One of the graduates is currently working in the strawberry industry and two students continued as graduate students on strawberry-related research projects. The remaining three graduated students are employed in agriculture, but not directly in the strawberry industry. The other 11 students did not graduate by the end of the project.

Through this project, relationships between the CPSC and the strawberry industry were greatly strengthened. There are several other students who did not participate in the internship program, but nonetheless worked for the CPSC, gained valuable training and ended up working in the strawberry industry. Although these students were not directly involved in the internship program, they benefitted from its existence. The CPSC will continue to facilitate work experience programs and provide qualified graduates.

The goals of the project were to identify internship opportunities, recruit students for these opportunities and steward the interns through their internship and associated experiences. The AEPS 470 course, which was developed specifically for this project, will continue for many years.

Project goals and accomplishments:

- Goal: Recruit and place 10-15 interns
    - Actual accomplishment: Placed 20 interns throughout the grant period

- Goal: Place 80 percent or more of graduates in strawberry industry or other Ag-related field
    - Actual accomplishment: Placed 100 percent of graduates in strawberry industry or other Ag-related field

- Goal: Create list of work experience opportunities with industry partners
    - Actual accomplishment: A list of opportunities was created each year based on industry input

- Goal: Fill 80 percent of work experience opportunities with Cal Poly students

- Actual accomplishment: Filled 100 percent of work experience opportunities with Cal Poly students

- Goal: Assess the quality of student work experiences
  - Actual accomplishment: Site visits and surveys by the PI were conducted to access that students had high quality work experiences

- Goal: Achieve 80 percent satisfaction of both employer and employee for all work experiences
  - Actual accomplishment: Based on exit surveys, there was a 100 percent satisfaction rate

Successful project outcomes:

1. Completed 20 internships with 17 students.
2. Achieved 100 percent employment rate for graduated interns.
3. All interns who have graduated are employed in agriculture; 50 percent are employed in the strawberry industry.
4. Provide experience for nine additional students who indirectly benefited from the internship program. They are all currently employed in the strawberry industry or pursuing graduate studies focused on strawberry issues.
5. Strengthened relationships among the CPSC and the strawberry industry through several collaborations with HR departments in several strawberry-centered companies (Smucker's, Cal Giant, Driscoll's, Cal Pacific, Andrew & Williamson, Naturipe).
6. Established a track record of supplying bright, young, talented college graduates to fill the needs of the strawberry industry.
7. Attracted Cal Poly students to the Strawberry Center's internship program – as evidenced by many more students requesting work experience opportunities than are available.
8. Began training and placing the next generation of leaders for the California strawberry industry.

Beneficiaries

The beneficiaries of this project are the individuals who have or will participate in the internship program and companies who are involved in strawberry production in California. These include, first and foremost, the Cal Poly students who participated in the internship program. These students are now entering the workforce and will become the future leaders of the strawberry industry and of agriculture. Additional beneficiaries are the companies who will benefit from the contributions of these students to their operations. Finally, California agriculture benefits by the infusion of bright, young college graduates entering agricultural careers to tackle current and future issues facing this dynamic industry.

The project benefited 25 students (17 interns and nine others who landed positions partly due to the activities of the internship program), 15 strawberry-related companies and the 400 California strawberry growers. The California strawberry industry is currently valued at over $2 billion. CPSC will continue to play a major role in sustaining this industry by training students to enter careers and be the future leaders in this industry. The internship program will be sustained beyond grant term with donations from partner corporations, the California Strawberry Commission, and individual growers.

Lessons Learned

The project exceeded expectations by attracting many students to the program and placing them in attractive careers. This includes students who were not directly involved in the internship program but benefited from the activities the program generated. Several influential growers commented that research center student training was key for the project success. These growers were extremely appreciative of this program and key influencers have commented on its value to the industry.

The developed course (AEPS 470) was very popular with students and with the strawberry industry collaborators. Students received a tremendous opportunity for exposure to issues and encounters with industry leaders. The invited speakers were given the opportunity to see the CPSC on an intimate level and interact with students one-on-one. The impact of this course on students and industry exceeded expectations on all sides.

Additional Information

Several internship spotlights with photos were posted to the Strawberry Center's Facebook page: https://www.facebook.com/cpstrawberrycenter

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 33	**Project Title:** Food Safe Integrated Nutrient Management of Organic Matter Amendments in Almond	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB15033	**Date Submitted:** December 2018
Recipient Contact: Sat Darshan S. Khalsa	**Telephone:** (707) 205-7007	**Email:** sdskhalsa@ucdavis.edu

Project Summary

Orchard soils in California are depleted of organic matter, yet abundant, underutilized sources of organic matter amendments like manure and green waste are available. Addition of these materials show potential to limit nutrient leaching that threatens environmental quality, while still enhancing soil fertility. Responses from grower survey showed clear belief in the benefits of these materials, but use is limited by concerns for food safety and nutrient availability. This project aimed to test how food safe use of organic matter amendments integrated with conventional fertilizer impact tree nutrition and soil health by measuring tree growth, leaf nutrient status, soil nutrient cycling and soil carbon; verifying food safe practices by screening for human pathogens on fruit at harvest; and monitoring grower perceptions. This was achieved with a mother-daughter participatory approach where research from one trial site in a randomized complete block design was replicated on smaller proximal trials.

Plant nutrients lost from the rooting zone directly threaten environmental quality in California and the sustainability of its agriculture. Organic matter amendments like manure and green waste contain both organic carbon and slow-release nutrients that will improve soil nutrient retention. However, there is little scientific evidence that demonstrates the benefits of these materials to tree nutrition and soil health for specialty nut crops like almond. From over 1,100 responses to recent survey, almond growers ranked food safety and nutrient availability as their top concerns regarding the use of organic matter amendments. Furthermore, most almond growers outline the most widespread production practice in established orchards is to exclude the application of organic matter amendments for a minimum of 120 days until harvest and to place materials like composted manure or green waste compost on the tree berm like mulch. The strategy that was replicated in this project maintains the benefits of no-till and reduces the food safety risk. With greater regulations for applied nutrients imminent, the necessity to demonstrate practices for organic matter amendments is timely and important because barriers to adoption are based on lack of information not on lack of interest.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The following is a summary of project activities performed by the research team:
October, November and December of 2015, the daughter trial participants and locations were finalized, conducted baseline interviews with growers and coordinated with suppliers of organic matter amendments. These activities were performed by the University of California (UC), Davis Postdoctoral scholar. Baseline trunk circumferences for all trees at all sites were measured in December 2015. Soil augering to 0-50 cm, salt extracts for NH_4^+, NO_3^-, PO_4^{3-}, K^+, TN and TOC followed by installation year one soil ion exchange resin (IER) units was separated into two different campaigns between the mother and daughter trials. The mother trial sampling occurred in October 2015 and the daughter trials were conducted in February 2016, different

than originally planned. The original proposed number of IER units was deployed despite being on a slightly different timeline. This unusual development was due to grower coordination and availability of undergraduate assistance. Soil augering to 0-10 cm, salt extracts for NH_4^+, NO_3^-, PO_4^{3-}, K^+ and early season sampling of mass loss of compost were conducted on an increased number of occurrences due to research desire to fit mass loss of organic matter amendments to decomposition curves. These activities occurred at 4-8-week intervals throughout the scope of the experiment. In July and August 2016, all the mother and daughter locations were visited for leaf tissue sampling and analysis of total N, P and K as well as collection of almonds at maturity and analyze for *E. coli*, *Salmonella* and *Listeria* using culture-based methods. Analysis of baseline samples using Lachat flow injection analysis, inductively couple plasma optical emission spectrometry and elemental analysis was conducted. Year two activities followed the same schedule starting in October 2016 through August 2017. The same team members performed the activities in year two compared to year one.

Significant results from this project including tree growth, leaf nutrient status, organic matter amendment decomposition, soil nutrient cycling and human pathogens are summarized herein. There was no difference in control and organic matter amendment treatments (referred to collectively as treatments) for tree growth averaging 9-10 cm per year across all mother and daughter trial plots. Similarly, there was no difference between control and treatment leaf N and P in both 2016 and 2017 across all mother and daughter trial plots. This result could be attested to the lack of N and P deficiency in the systems due to ongoing grower N fertilization and the general lack of P deficiency of orchard soils. Leaf K was greater in the composted manure treatment in 2017 at both the mother and daughter trials although not significantly different. This result could be the result of the semi-annual orchard K fertilization and the high K demand of almond fruit. This result is interesting despite these young trees not having a significant K demand. There was a more pronounced effect of the treatments on leaf K compared to the control on the daughter trials on sandier soil. The one daughter trial on a more clayey loam soil showed a lower effect on leaf K. This result is most likely due to increased soil K retention in sandy soils due to organic matter amendments increasing cation exchange capacity. All mother and daughter trials demonstrated higher soil total organic carbon (TOC) and nitrogen (TN) and were significantly greater at mother trial in 2016. The treatment effect on TOC and TN was more substantial on sandy daughter trials compared to the more clayey loam daughter trial. For soil sampled at 0 – 50 cm at the end of the growing season there were significant difference in inorganic K but, not in N and P. These results were similar to what was found for leaf N, P and K and suggest nutrient availability is both affected by the treatments and translated to an impact on overall tree nutrition. The effects on N availability gathered from IER units differed between 2016 and 2017. In 2016, there were no significant differences between the control and treatments for N availability even though the treatments were greater than the control. However, in 2017 those differences increased and both treatments of composted manure and green waste compost were significantly greater than the control. These results can be explained by the reduction in TN from 2016 to 2017 in the treatments. The total N found in the soil and derived from the treatments in 2016 became available in 2017 and contributed significantly to greater N availability. All analyses of organic matter amendments almond fruit for presence of human pathogens were returned as negative. This result demonstrates that the food safe use of organic matter amendments is possible in California orchards.

Grower participant interviews and outreach activities commenced during this project. After year one and year two, all participating growers recognized that favorable results from this experiment would take time to occur. Despite the lack for conclusive results from 2016 all growers continued the research through 2017 and even continue to carry out the trial beyond the duration of the project. Nevertheless, growers were comfortable with

the lack of food safety risk in trial participation but, were not very confident about making their private orchards open to the public for grower field days. This grower concern along with the lack of definitive results informed the decision to forgo public field days with this project. However, a private field day in one of the daughter trial orchards with 25 different UC Cooperative Extension farm advisors was carried out on May 23, 2018. Furthermore, a workshop was held in at the UC Cooperative Extension office on June 8, 2018 and was attended by 30 different growers, advisors and students. An additional favorable outcome from this project was the identification of fertilizer reduction for the use of organic matter amendments. The Almond Board of California awarded funding to test different approaches of fertilizer reduction that will be tested in the field beyond the duration of this project.

The overall scope of the project only benefitted almonds.

The Almond Board of California provided ongoing funding of components of the mother trial.

Goals and Outcomes Achieved

Measurable outcomes were measured in tree nutrition, soil health, food safety, and grower perceptions. In tree nutrition, the research team observed no loss in productivity by measuring how difference in trunk growth and adverse effects on leaf nutrient status by measuring plant essential nutrients from leaf sampling. These outcomes signal to the goal that integrated nutrient management of organic matter amendments can effectively reduce dependence of conventional fertilizer in almond. The baseline data collected in tree nutrition allowed the research team to design approaches to compare 20 percent substitution of conventional fertilizer with conventional grower practice. The baseline data from this project also confirmed the outcome that fertilizer reduction using organic matter amendments is achievable. In soil health, the team measured greater soil nutrient retention in the rooting zone from the treatments compared to the control from higher concentrations of TOC that supported higher TN in 2016. It seems that the subsequent year of 2017 showed higher N availability. The baseline data from soil health was unable to verify if nutrient use efficiency increased during this project. Much of the organic matter amendments was stored in the soil but, there were no differences in N uptake. This result is due to either 1) low yield from young trees reduced overall nutrient demand; and 2) The project duration of two growing seasons is not sufficient in length to measure impacts on nutrient use efficiency from use of organic matter amendments in almonds. In food safety, the team observed a sustained absence of human pathogens on fruit at harvest and this result built greater confidence among grower participants to continue using organic matter amendments in the trials. The baseline data in food safety verifies that elimination of the pathogen risk associated with organic matter amendments is achievable by using composted materials and maintaining adequate exclusion periods of greater than 120 days. Finally, favorable perceptions of growers will lead to greater interest in expanding adoption and a willingness to recommend treatments to their neighbors. All participating growers in addition to farm advisors and workshop participants provided feedback that the practice of using organic matter amendments in almonds offers favorable results. The baseline data in grower perceptions showed favorable views of organic matter amendments by all grower participants. An increase of 50 percent was expected in the current levels of organic matter amendments by grower participants. All grower participants continue to apply organic matter amendments in the research trials initiated by this project and multiple growers expanded use of organic matter amendments to additional acreage beyond the initial scope of this project. The key benchmark is the comparison between the effects found at the mother trial site and other daughter trials. The research team observed some parameters to be similar between mother and daughter trials like TOC, TN, leaf N and P but, other parameters like soil exchangeable K and leaf K differed by soil type. It is imperative to evaluate

performance for a wider range of grower operations and environmental conditions. These measurable outcomes are expected to continue to benefit growers, certified crop advisers, extension agents and researchers of fruit and nut crops by displaying the efficacy of this sustainable production practice.

All the measurable outcomes presented herein fit the duration of the project period. However, all the participating growers continue to apply the treatments and maintain those experimental plots. This outcome was unexpected, and the results of this work will progress beyond the scope of this initial project.

To date the growers have carried out the project treatments for the grower season of 2018 and intend to apply organic matter amendments for 2019 as well.

Measurable outcomes were in the areas of tree nutrition, soil health, food safety, and grower perceptions. Baseline data from 2016 shows trees continued to grow and acquire nutrients into 2017 without differences in trunk diameter, leaf N and P but, not in leaf K. In soil health, levels of TOC and TN increased in 2016 and were higher than baseline data gathered in 2015. This result shows that treatments increased TOC and TN despite the lack of significant differences in 2017. Nitrogen availability from IER units were equal when the project started, increased slightly in 2016 and was significantly greater for the treatments in 2017. Baseline data from the survey of almond growers shows that food safety is the number one concern among growers and grower perceptions of organic matter use revolve around concerns for food safety. The research team were able to demonstrate food safe use of organic matter amendments in this project. Progress was made in that the growers continue to want to participate in the trials moving forward however, concern remains in that the same growers were not very enthusiastic to host a field day that would be open to the public.

Despite the lack of significant differences in 2017 for TOC and TN, the use of organic matter amendments is a proven way to increase soil organic matter and build soil nutrient reserves. All the mother and daughter trial treatments were implemented as organic matter amendments as a supplement to (or in addition to) conventional fertilizer. Now, there is a renewed opportunity to try and implement substitution studies to reduce synthetic fertilizer use and integrate organic matter amendments at a cost savings to the grower. Overall, there were no negative effects to tree productivity and nutrition and this is a success to try and refine practices moving forward. Finally, all the growers want to continue to participate in the experimental trials so, there is opportunity to implement long term trials that will lead to more meaningful results over time.

Beneficiaries

Several different groups benefitted from the completion of this project. The participating growers and those growers that participated in the workshop possess the most up-to-date information on the use of organic matter amendments in orchards within California. The private field day with UC Cooperative extension farm advisors was very successful as the participants were given the latest information on the use of organic matter amendments and they will be able to share these results within their communities. Finally, results will be shared with almond processors so, they better understand that organic matter amendments can be used both in a food safe manner as well as a sustainable production practice.

The main beneficiaries of the project include over 600 almond growers and UC Cooperative Extension farm advisors. At minimum 25 UC farms advisors benefitted from the project due to participation in a field day on May 23, 2018 representing all the major almond growing counties in California. The main vehicle for

information dissemination would be farm advisors returning to their host counties and relaying data results to their communities.

Lessons Learned

Positive results include working with engaged grower participants who show an innate interest in the project and seek to cooperate to the best extent possible. Additional positive results include working with different investigators across multiple disciplines to form an integrated project that touches on tree productivity and nutrition, soil health, food safety and grower perceptions. Negative results include the challenges associated with information dissemination for project that require more time to yield definitive results.

Goals and measurable outcomes were achieved including completing all the planned outreach activities and being able to measure the impact of organic matter amendments on nutrient use efficiency. The results of this project could not be 100 percent predicted so; it's unclear how this work would be done differently. One option would be to hold smaller outreach events in lieu of larger public field trials. One option for measuring the impact of organic matter amendments on nutrient use efficiency is to conduct longer field trials over more than two growing seasons.

Additional Information

See Attachment 1.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 34	**Project Title:** Water Stewardship and Drought Resilience in the Russian River Watershed	
Grant Recipient: California Land Stewardship Institute	**Grant Agreement No.:** SCB15034	**Date Submitted:** December 2018
Recipient Contact: Laurel Marcus	**Telephone:** (707) 253-1226	**Email:** laurelm@fishfriendlyfarming.org

Project Summary

The conflict between water for farms and endangered salmonids is a significant problem for specialty crop growers in the Russian River watershed. Using water for frost control is essential for winegrapes and pear crops. A program of water demand reduction, stream flow gaging and coordination of diversions between growers was needed to avoid sudden flow reductions in streams and stranding of salmonids. Growers can reduce water demand through implementation of Beneficial Management Practices (BMPs). Involving growers in stream flow gaging and use of flow data in discussions of coordination of water diversion in tributaries can provide a long-term solution to avoid environmental effects of using water for frost control and keep specialty crop growers in business.

Specialty crop growers in the Russian River watershed cannot remain in business if they cannot use water for frost control. Springtime temperatures drop to freezing and new growth on vines and trees must be protected from frost damage or no fruit will develop. Water is applied continuously with overhead sprinklers. As the water changes to ice it releases heat and keeps the new bud from freezing. Fisheries agencies (California Department of Fish and Wildlife, National Marine Fisheries Service) have stated that when sprinklers are turned on over large areas of specialty crops all at once water levels in streams can drop affecting salmonids. There are no alternative frost control measures when temperatures drop below 29°F as they do in the Russian River. The California State Water Resources Control Board passed a regulation over specialty crop growers only in the Russian River basin requiring water management, stream flow gaging and other actions. This project was both important and timely to keep specialty crop growers competitive and reduce effects on endangered salmonids.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

California Land Stewardship Institute (CLSI) coordinated project activities with the Mendocino County Farm Bureau, Sonoma Winegrape Commission, Russian River Water Conservation Council, Mendocino Winegrowers Inc. to inform specialty crop growers of workshops. CLSI also coordinated with the California Department of Fish and Wildlife and National Marine Fisheries Service on the locations of gages in high priority tributaries. As part of the match for this grant, staff coordinated extensively with the Natural Resources Conservation Service.

CLSI held eight grower workshops in 2016, six in 2017, and four in 2018. Topics covered included: stream flow monitoring (location selection, gage selection and installation, channel surveys, discharge measurements, rating curve development, maintenance, diversion coordination, creek assessments), water use metering, groundwater level measurement, frost water use efficiency and reduction demand, and frost water use record keeping.

CLSI operated the McNab Creek gaging network (Attachment 1). Each year following the frost season CLSI evaluated gaging records with frost event dates. No frost signals were found in this network.

CLSI evaluated gaging records, frost water use records and water systems for each of the diverters on McNab Creek. All diverters were using BMPs to reduce frost water demand and there were no direct diverters or frost signals.

CLSI completed site reconnaissance and outreach to growers for the Dooley/McDowell Creek system. This gaging network was installed in January-March 2016 (Attachment 1).

CLSI surveyed creek topography at each gage in the Dooley Creek network.

CLSI operated the Dooley/McDowell Creek gaging system, and following the winter of 2016/2017 had to replace gages and outside staff gages at three locations.

CLSI evaluated gaging records, frost water use records and water systems for each of the diverters on Dooley/McDowell Creeks. All diverters were using BMPs to reduce frost water demand and most had storage ponds. During the 2016 frost season there was a frost signal at Dooley Gage 1. This station is directly downstream from an on-stream reservoir and flow dropped when frost pumps turned on and water stopped spilling from the reservoir. CLSI worked with the grower and prepared a corrective action plan. The diverters would maintain the water level in the reservoir to keep flow in the creek and divert from their other ponds. CLSI also identified a direct diverter on Dooley Creek that needs to install a storage pond. CLSI will continue to work with this diverter.

CLSI completed site reconnaissance and outreach to growers in the Feliz Creek system. This gaging network was installed in November 2016 (Attachment1).

CLSI surveyed creek topography at each gage in the Feliz Creek network.

CLSI operated the Feliz Creek gage network and following the winter of 2016/2017 two of the gages had to be replaced along with outside staff gages.

CLSI evaluated gaging records, frost water use records and water systems for each of the diverters on Feliz Creek. All diverters were using BMPs to reduce frost water demand and there were no direct diverters or frost signals. All diverters have storage ponds.

CLSI completed site reconnaissance and outreach to growers for the York Creek and West Fork Russian River gaging networks. These gaging networks were installed in November 2017 (Attachment 1).

The following data were collected, analyzed and actions taken:

- Number of gage networks designed and number of individual gages installed. Based on these data CLSI requested a contract and budget change to allow for an additional gaging network to be installed.
- Data sets from the gages were evaluated for missing data. No major data gaps were noted.

- Quality assurance/quality control forms for discharge measurements were reviewed. No problems were identified.
- Topographic assessments of gage sites were reviewed along with potential stranding locations. No problems were identified.
- Evaluate all data sources to determine where problems occur. Gaging data was reviewed with growers as were a series of evaluations of farm water supply infrastructure and water efficiency BMPs. There were few problems and only one diverter identified who needs a storage pond.

Only specialty crop growers participated and benefited from the project.

Project partners:
The Mendocino County Farm Bureau, Mendocino Winegrowers Inc., Sonoma Winegrape Commission and the Russian River Water Conservation Council all advertised the workshops and distributed notices to their members. The Mendocino County Farm Bureau and Sonoma Winegrape Commission allowed CLSI to use their meeting rooms for a number of workshops and meetings. The Natural Resource Conservation Service provided presentations on irrigation water use efficiency. The National Marine Fisheries Service worked with CLSI to install Gage #4 on Dooley Creek.

Goals and Outcomes Achieved

Expected Measurable Outcome #1: “Goal: Increase the number of growers that implement improved water stewardship methods. Target: 50 percent of the growers in the four high priority tributaries will utilize water stewardship measures.” CLSI completed evaluations of the water supply infrastructure, frost and irrigation systems for the diverters in the McNab, Dooley, Feliz and York Creek tributaries. Over 50 percent of the diverters are currently using water stewardship BMPs. Sites were evaluated for on-site temperature monitoring for frost control, soil moisture monitoring and irrigation system efficiency, water storage or groundwater for frost water instead of direct diversion, water management for on-stream ponds to provide continuous downstream flows, water use metering, and frost water use recording. With each grower CLSI discussed additional BMPs needed or a need for additional infrastructure. One diverter in the Dooley Creek watershed needs to change infrastructure to avoid effects on stream flow. All the other growers had storage or a well and do not directly divert. CLSI reviewed frost diversion and gaging records with the growers and discussed any needed changes or coordination of diversion. There was one incident where an on-stream reservoir stopped spilling when frost pumps were turned on. This was corrected though collaboration with the grower. All the growers were using BMPs to reduce their water demand meeting Expected Measurable Outcome #1 and Performance Goal 4.

Expected Measurable Outcome #2 “Goal: Increase the knowledge of specialty crop growers about water stewardship practices. Target: 50 percent of growers attending the workshops will show an increase in understanding of water stewardship practices.” CLSI held 15 workshops on water stewardship topics. CLSI surveyed the specialty crop growers in the frost program regarding use of water stewardship BMPs. These BMPs include: on-site temperature monitoring for frost control, soil moisture monitoring and irrigation system efficiency, water storage or groundwater for frost water instead of direct diversion, water management for on-stream ponds to provide continuous downstream flows, water use metering, and frost water use recording. CLSI found over 50 percent of the 193 growers surveyed had a thorough understanding of water

stewardship BMPs and were implementing these BMPs meeting the target of Expected Measurable Outcome #2 and Performance Goal 5.

Expected Measurable Outcome #3 "Goal: Enhance specialty crop grower competitiveness by increasing compliance with state and federal recovery efforts for listed salmonids by improving instream flow conditions. Target: Establish and operate three additional gaging networks on three high priority tributaries during the project period." Three gaging networks were installed. The Dooley Creek network was installed in January-March 2016. The Feliz Creek network was installed in November 2016. The York Creek network was installed in the November 2017. An additional network was installed on the West Fork Russian River once an amendment to the contract was completed. The installation of these gaging networks fulfills Expected Measurable Outcome #3 and Performance Goal 1. As part of this project CLSI operated the three gaging networks and completed topographic surveys fulfilling Performance Goals 2 and 3.

The project fulfilled the three measurable outcomes. CLSI evaluations of farm water systems and BMPs used demonstrated that greater than 50 percent of the growers in the high priority tributaries are using water stewardship measures (Outcome #1). The surveys of 193 growers in the frost program demonstrated an understanding of water stewardship practices by greater than 50percent of growers (Outcome #2). Three gaging networks were installed fulfilling Outcome #3.

The baseline for Outcome #1 was zero use of water stewardship BMPs. Following this project the evaluations found over 90percent of the growers in the high priority tributaries were using water stewardship BMPs. The grant target was 50 percent so the outcome target was exceeded.

The baseline for Outcome #2 was zero understanding of water stewardship practices by growers in the frost program attending workshop. The surveys found 72 percent of growers had a thorough understanding of water stewardship practices. This exceeds the grant target of 50 percent.

For Outcome #3 the baseline was one installed gaging network in McNab Creek. The target was installation of three additional gaging networks. Four networks were installed exceeding this target.

Highlights:
Outcome #1 was implemented by over 90 percent of the growers in the four high priority tributaries. Outcome #2 was implemented by 72 percent of the growers surveyed in the frost program. Outcome #3 was implemented by installation of four gaging networks, maintenance of these networks, analysis of the data and surveying of the channel along with evaluation of frost diversion data to demonstrate that in 95 percent of incidents specialty crop growers were not dewatering streams and affecting listed salmonids. For the one occurrence where a frost signal was recorded a change in the upstream grower's water management was implemented removing the problem.

Beneficiaries

This project benefitted the 193 specialty crop agricultural operations in the Mendocino Russian River Frost Program. This project allowed for the installation of needed gaging networks to keep all these operations in compliance with state regulations. Additionally, this project provided the information and assistance needed for specialty crop growers in both Mendocino and Sonoma Counties to reduce their frost water demand.

There are 193 separate specialty crop agricultural operations in the Mendocino Russian River Frost Program who benefitted from this program. There were another 85 frost diverters in Sonoma County who attended workshops and benefited from this project. If the 278 beneficiaries save an average of $100 in Water Demand Management Program per acre fees, this project has the potential to save $27,800 annually.

Lessons Learned

CLSI staff learned how to analyze gage network data for minor fluctuations in flow to determine effects of frost diversions and how to present this information to growers. Staff worked collaboratively with growers on changes to their water use, an often emotionally-charged and difficult subject. Staff found that growers have many good ideas for increasing water use efficiency. Staff also learned how difficult gage maintenance and repair can be in a very wet winter.

The most unexpected outcome was how few frost signals there were in the 18 gage data records over the course of this project. The fisheries agencies stated that the use of water for frost control dewatered most of the tributaries in the Russian River. There was one frost signal at one gaging station over the three frost seasons included in this grant. This problem was readily addressed by the grower by changing water management.

Additional Information

See Attachment 1 – Maps and Photographs of Stream Flow Gage Networks

USDA Project No.:	Project Title: Improving Salinity Management Strategies for Almond Grown under Micro-Irrigation	
35		
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB15035	**Date Submitted:** December 2018
Recipient Contact: Patrick H. Brown	**Telephone:** (530) 752-0929	**Email:** phbrown@ucdavis.edu

Project Summary

Competition for high quality surface irrigation water has resulted in increased use of groundwater and decreased water availability to leach excess salts and this has dramatically increased the salt load in California almond production. An estimated 10 percent of almond acreage is salt impacted and an additional 30 percent is now utilizing saline irrigation water with an estimated annual economic impact of $100-400 million (three to six percent of $4.7 billion crop value). Almond is a salt-sensitive crop however information on the physiological effects of salinity stress on almond trees and the mechanisms of tolerance is not available. There is a wide diversity of tolerance to salinity among the available almond rootstocks/cultivars however the physiological basis for these differences is not known. To develop salt tolerant almond varieties breeders and nurseries need quick, reliable screening strategies which must be built on a sound understanding of plant physiology. Salinity management strategies typically involve application of excess water to leach salts from the effective root zone. The majority of almond is irrigated with micro-irrigation which results in highly non-uniform salt deposition and strategies to manage salinity in this context have not been developed. Nitrate leaching is a serious problem in California and micro-irrigation strategies to simultaneously leach salt, while retaining nitrate in the rooting profile have not been developed. This project characterizes salt uptake and sensitivity of germplasm and use this information and solute transport modeling to model salt deposition in the root zone, improve breeding programs, inform grower germplasm choices and optimize irrigation strategies. The objective is a characterization of rootstock and cultivar salt tolerance and the development of irrigation strategies that achieve adequate salt leaching, minimal nitrate leaching and maximal crop productivity under diverse soil and environmental conditions.

Almond has been classified as salt sensitive and growers typically apply substantial leaching fractions to mitigate the accumulation of salts in the root zone. This additional water moves substantial salts into ground and surface waters and decreases water use efficiency. Furthermore, the use of a leaching fraction to remove salts results in nitrate losses from the root zone increasing nitrate contamination of groundwater. To minimize these effects there is a need for a better understanding of almond response to salinity and development of irrigation practices that simultaneously minimize salt damage, minimize nitrate leaching and maximize water use efficiency. While micro-irrigation is the most water efficient means to irrigate, there are no guidelines for salinity management in these micro-irrigation systems. There is a lack of physiological understanding of how micro-irrigation influences crop salt sensitivity as well as a lack of information on the leaching requirements of different almond germplasm, which vary greatly in tolerance. The development of salt tolerant rootstock could have a profound effect on water use efficiency by reducing the volume of water required to maintain root zone salinity below the critical salinity threshold. The almond industry has been the target of many news releases emphasizing the negative impact of almonds on water use and salinization of soils. Enhanced use of micro-irrigation and increased water efficiency are essential if the industry is to

address these concerns. This project has strong industry support, and is scalable to all almond production areas and to other micro-irrigated tree crops. The characterization of germplasm and development of optimized irrigation strategies has an immediate value to nurseries and growers.

This project will have a significant impact and importance for the almond industry. Several news releases have targeted almond industry emphasizing the negative impact of almonds on water use and salinization of soils. Currently micro-irrigation is the most water efficient means to irrigate, however there are no guidelines for salinity management in these micro-irrigation systems. In addition, the lack of physiological understanding of how micro-irrigation influences crop salt sensitivity as well as a lack of information on the leaching requirements of different almond cultivars, which vary greatly in tolerance, will have a significant environmental impact that will be exacerbated if nitrate leaching is not considered. Improved management practices and understanding of salt tolerance of different rootstocks immediately benefits nurseries and growers.

Salinity management practices have a fundamental importance in California because water resources become more limited and groundwater use expands. Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) and the water boards and districts recognize salt management as a critical need with critical knowledge gaps. At the national level, salinity research is also a high priority. Understanding the impact of salinity, optimizing water use efficiency and minimizing nitrate leaching are fundamental needs for irrigated agriculture in California. Management guidelines for different conditions (such as climate, soil, salinity level) are will have an immediate environmental benefit for California. This project will generate new scientific/technical knowledge with significant environmental benefits for Californian agriculture in the short and long term.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The following activities were accomplished during the grant term:

Outcome 1: An improved and updated salinity screening test for germplasm screening by nurseries/breeders was developed and extended. Screening can be performed with a 40-60 day exposure to a single salt concentration (40mM) and subsequent measurement of leaf tissue sodium (Na) and chlorine (Cl) concentrations.

Presentations and posters (Salinity Stress in Almond, Rootstock Screening and Tree Response to Non-Uniform Salinity) by project collaborators, disseminated project results during the Almond Board of California (ABC) conferences.

This outcome was also communicated directly to nurseries. Further, the ABC coordinated a workgroup meeting of research teams conducting salinity research to improve data collection, integrate studies and improve communication across the almond industry. Six of the nurseries leaders in the market attended the conference presentations and received the project methodology and results.

Outcome 2: Improved micro-irrigation strategies to minimize the impact of salinity in almond.

Experiments under non-uniform saline conditions were performed to understand tree response under micro-irrigation. Specific experiments under solution culture and substrate were performed to understand effect of salinity on water-uptake and to test plant root responses expected in the field under differential root sub-zones (spatial variability). Pot experiments were used to validate results observed under hydroponics. Results demonstrate that almond root rapidly responds to the local root environment with water uptake greatly diminished in saline root zones if there is availability of non-saline water in other root zones. The availability of nutrients appears to be critical to this response thus suggesting that strategies to leach salts from root zones will only be successful if there are adequate nutrient reserves in the non-salinized portion of the root volume.

Outcome 3: Expand the ability of both farm advisors and growers to develop optimal site-specific irrigation management. An experiment using lysimeters above ground was installed in the University of California (UC), Davis Plant Sciences field to measure under controlled conditions, dynamics of water, salt and nitrate in the root zone of almond trees. This outcome was delayed, mainly by wet winter and complexity of field condition in installation of both volumetric and weighing lysimeters. This situation prevented completion of this goal however the project team obtained additional funding from other sources to complete this task.

This project does not enhance the competitiveness of non-specialty crops.

Significant collaboration was made through the following:

For outcome 1: Project Scientist, Junior Specialist, undergrads, and Project Director were involved in all experiments required to conduct “germplasm salinity screening,” its data collection, and data analysis.

For outcome 2: Graduate student researcher, Junior Specialist and undergrads, and Project Director were involved in all experiments required to conduct “non-uniform root zone salinity,” its data collection and analysis.

For outcome 3: The Project Scientist, Graduate student researcher, Junior Specialists, and Project Director were involved in installation of weighing lysimeter, calibration of load cell for weighing lysimeter, calibration of soil moisture sensors, manufacturing neutron probe access tubes, conducting simulation scenarios, developing online tool, and day-to-day maintenance of volumetric lysimeters and irrigation/fertigation system.

Goals and Outcomes Achieved

Outcome 1: The germplasm salinity screening was completed. Several exploratory experiments using pot system with substrate were performed in order to determine: salt concentrations, salt types, and time of salt exposure toxic for a tree. Optimal saline stress conditions were used to create a protocol to test salt tolerance for almonds. This initial step was critical to improve understanding of almond physiology under salt stress. Historically almond has been classified as a salt-sensitive crop with a cutoff ECe of 1.5 dS/m, this assessment is however an oversimplification based largely on research with Lovell rootstock. Results of experiments suggest that this value may be over conservative (at least in short term) and demonstrated the critical importance of salt type, rootstock and cultivar on this dynamic. The project salinity rankings largely replicated the field experience and it was hypothesized that soil root zone heterogeneity can explain slight differences in tree response between field and pot.

Based on several pre-evaluation experiments results, a rapid 60-day screening protocol was successfully developed.

Salinity tolerance of different almond rootstocks were studied by monitoring tree growth and salt accumulation in leaves. One year old grafted plants of Nonpareil on different rootstocks were planted in seven gallon pot having Calcined clay (Turface). Plants were irrigated with nutrient solution having all essential nutrients with salinity of ~one ds/m. Treatments consisted of control and 4.5 ds/m salinity using ~ two NaCl and one Na_2SO_4 to represent Na dominant salinity. Leaves were analyzed for Na and Cl concentration (Figure 1). Plant canopy size was estimated by taking pictures and analyzing images (Figure 2). Rootstocks varied in Na and Cl accumulation in leaves. Rootpac-R and Nemaguard accumulated more Na and Cl in leaves whereas Bright 106, Bright Hybrid, Corner Stone and Empyrean one accumulated significantly less Na and Cl in leaves. Growth of trees on all rootstocks declined for all salt treatments, however trees on rootstocks which accumulated less Na and Cl were less affected by salinity. Growth of RootPac-R appeared to be most sensitive to salinity whereas growth of Bright 106 was least affected by salts.

Screening of 12 prominent rootstock varieties has been conducted and rootstocks have been ranked. A rapid screening method for salinity tolerance determination has been developed. Nemaguard was identified as the most saline sensitive rootstock. Hanson536 were significant more salt tolerant than Nemaguard. Empyrean-1 and Viking were unaffected by salinity for the duration of the experiment.

Cultivar experiments: Nonpareil was significantly more tolerant of Na than other cultivars primarily as a result of the capacity of Nonpareil to store Na in woody tissues whereas Fritz and Mission were unable to do this and accumulated substantially more Na in their leaves.

Salt type experiments: KCl was found to be a much more potent salt source than NaCl when presented in equimolar concentrations. The mechanisms of this response have not been determined.
Double-graft experiment: significant differences in leaf Na accumulation patterns of the Nonpareil and Mission cultivars grafted on Nemaguard were found. Leaf Na concentration of Mission were twice as high as Nonpareil reflecting the exclusion of Na from leaves and storage in woody tissue of Nonpareil.

Outcome 2: The effect of salinity on growth and water uptake was completed.
A set of experiments were designed based on the initial physiological knowledge generated during the first step of this project. The design also considered different saline environments expected to be observed in different sub zones of the root zone of a single plant when micro-irrigation systems are used in orchards. This set of experiments contributed to the understanding of physiological root responses in terms of water, nitrate, sodium and chloride uptake. A split root methodology in which roots of a single plant were divided in two equal halves and different saline treatments were applied to different areas of the root system was performed. Split roots experiment using: Nemaguard seedlings (for solution culture) and Nonpareil trees grafted on three different rootstocks were used to measure root response under heterogeneous saline condition and its effect in the short term (28 days/hydroponics) and long term (two growing seasons/substrate). Plant growth and root activity (uptake of water, salt ions and mineral nutrients) were measured to understand plant-soil dynamics.

Effects of non-uniform root zone salinity on tree growth and leaf Na and Cl accumulation has been studied. Root of 90 Nonpareil trees grafted on Nemaguard, Hansen 536 and Empyrean 1 were split into two equal

halves and placed in special pots to accommodate split roots. Three salt levels (control, 20 millimolar (mM) (low salt) and 40 mM (high salt)) were applied with six treatment combination to each rootstock. Six treatments- control/control, control/low salt, control/high salt, low salt/low salt, low salt/high salt and high slat/high salt were applied to five replicated trees. Leaf samples were collected periodically for Na and Cl analysis and tree growth was estimated by photographic analysis (Figure 3). Leaf Na^+ and Cl^- concentrations decreased for all rootstocks when partial good root conditions were provided. Tree growth under non-uniform salinity conditions was significantly improved over uniform salinity.

A hydroponic experiment was used to check the effect of salinity in different areas of the root zone on water and nitrate uptake. A total of 45 seedlings of Nemaguard (rootstock commonly used in commercial orchards across California) were used in each experiment. Highly plastic root responses were observed when salinity was applied. Under conditions where nutrients were available in both root-zones, water and ion uptake rapidly allocates to root sub-zones in the non-saline environment (Figure 4). The uptake of water and saline ions was greatly enhanced in areas of low salinity and diminished in saline root sub-zones; however when nutrients were provided to both root sides, a marked increment in water and salt uptake from the saline root-zone occurs (Table 1). The striking effect of nutrients on plant response has tremendous implications for nutrient management in salt affected root zones (Figure 5). The lack of nutrients in one root zone decreases the water uptake from that zone. If nutrients are limited to the salty root zone then preferential water uptake will occur from the salt side with resultant enhancement of salt uptake.

All rootstocks when grown with a portion of roots exposed to salinity with remaining portion of root system grown in low saline water exhibited significant preferential water uptake from the less-saline side. In pot studies a significant decrease in total plant salt accumulation was observed when one half of the root system was exposed to low saline solution. This result has an important relevance to low volume irrigation management strategies where non-uniform salt deposition frequently occurs.

Outcome 3: The modeling and online tool, was not completed during the grant term. The lysimeter experiment has been fully established; experiments and data collection will be continued utilizing ABC funds that have been received for project extension. New experiments and data will be collected and used to develop models to understand water, nitrate and salt dynamics in the soil. Data collected in season 2019 will be used to develop/validate model to predict dynamics in the soil. Data will allow obtaining the final version of the irrigation management tool for farmers and growers.

Outcome 3 was a project long-term objective. This experimental system is now well established and funding has been obtained from other resources to achieve the long-term goal and measures.

This project has been mostly accomplished. However, outcome 3, which has a direct application into the field (and the most difficult to complete), has not been finished. The delay in data collection was due to high amounts of rainfall during the winter, which resulted in the soil being too wet to support the large machines necessary to fill the lysimeters with soil. In addition, the required soil was unavailable due to wet conditions.

An experiment using lysimeters above ground was installed in UC Davis Plant Sciences field to measure under controlled conditions dynamics of water, salt and nitrate in the root zone of Almond trees (Figure 6). This outcome has been delayed, mainly by wet winter and complexity of field condition in installation of both volumetric and weighing lysimeters. Currently, lysimeters are fully equipped to collect data of

water/nitrate/salt movement in the root zone. Root growth is being estimated with transparent tubes (mini-rhizotron tubes) with measurements collected during season 2018 and 2019 being used to estimate root distribution and growth rates in response to heterogenous soil salinity. Soil hydraulic parameters required for calibration of sensors has been determined (Figure 7). Those parameters will be useful to determine irrigation treatments and performing computer simulation which will predict expected values to be observed in the orchard. All probes are being installed in the field. Simulations of water and nutrient distribution in a drip irrigated soil were carried out using the software HYDRUS 2D. The simulations show changes in nitrate concentration and water content in the soil profile under a single dripline after a single irrigation event and were run for various soil types, irrigation timings and fertigation managements.

A beta version of on-line tool for irrigation and fertigation management is currently under development. The on-line tool has not been released publicly due to compatibility issues with http-based websites. Once the website compatibility issues are resolved, the on-line tool will be available on the UC Davis website with an anticipated release date in the fall of 2019. The site will be improved periodically. The full version will be delivered once the observation/validation process is performed with lysimeters during the 2019 season.

Experimental design, instrumentation and installation of lysimeters has been established. Almond trees have been planted in large tomato truck bins measuring 28 x 8 x 5 ft (L×W×D) with two trees at a spacing of 14 foot. Eight treatments × three replicates for a total of 24 tomato truck bins are being used. Soil physical, chemical and hydraulic parameters were determined. Bins were instrumented with soil sensors, neutron probe, minirhizotron tubes, and suction samplers.

Beneficiaries

The improvement and update of salinity screening protocol for rootstock germplasm by nurseries/breeders, outcome 1, had a direct impact for nurseries and growers. The protocol has been shared with nurseries, almond growers, farm advisors. The availability of this knowledge will be useful for growers during establishment of new orchards in areas with a risk of salinity.

Results of outcome 2 provided insight for improved salinity management. However, results need to be validated in the field in order to release them to the public (outcome 3). Biological parameters estimated in this part of the project provide the baseline information for the mathematical simulations required to develop an approach to irrigation management to achieve nitrate sensitive salinity management.

Results were shared during the ABC conferences in 2016, 2017, and 2018 by poster and oral presentation. Each conference had over 3,500 attendees composed of gathering growers, processors, suppliers, distributors, marketers and researchers from around the globe. Since a large proportion of the almond production region of California is currently utilizing groundwater and recycled/drainage impacted surface waters containing significant salinity, outputs of this project have a direct impact in the management of those orchards. Results were also presented at the 2016 and 2017 California American Society of Agronamy (ASA) meetings, the Western Plant Health Association (WPHA) meeting in November 2018, and the California Department of Food and Agriculture-Fertilizer Research and Education Program meeting (CDFA FREP) in October 2018. There were approximately 400 attendees at each ASA meetings, the WPHA meeting had approximately 100 attendees, and the CDFA FREP meeting, had approximately 340 attendees.

This project has already helped nurseries by providing a foundation for selection/screening and development of superior germplasm and adapted irrigation strategies. The research will inform the management of agricultural discharges and will lead to innovation in the irrigation industry and improved policy.

Lessons Learned

The main limitation/lesson that the project team needed to face was a result of weather conditions. This could not be predicted and due to the short nature of the grant represented a significant challenge. In projects with perennial species, which are the most important specialty crops of California, the availability of longer grants is essential. This is particularly important when working with deciduous perennials for which working during dormancy avoids disruption of root grown pattern (when placing probes and tubes) and it also avoids apply an extra stress to trees.

Far greater differences in salt tolerance were observed than was expected suggesting significant potential for breeding strategies. The highly plastic nature of almond root to non-uniform root salinity was unexpected outcome and suggests that irrigation strategies can be used to manage salinity in almond.

Weather challenges in 2016 delayed experimental installation and prevented outcome 3 completion. This delay was mitigated by increased activity in other aspects of the project.

Additional Information

More information is available on http://calasa.ucdavis.edu/
See Attachments 1-3.

USDA Project No.: 36	**Project Title:** Management Practices to Minimize Stormwater Pollution from Macrotunnel Production Systems	
Grant Recipient: Ventura County Resource Conservation District	**Grant Agreement No.:** SCB15036	**Date Submitted:** December 2018
Recipient Contact: Jamie Whiteford	**Telephone:** (805) 764-5132	**Email:** jamie.k.whiteford@gmail.com

Project Summary

This project focused on understanding the environmental and economic impacts of stormwater management practices in macrotunnel production systems. Macrotunnel-grown specialty crops contribute over $1 billion to California's economy and these production systems are one of the state's fastest growing agricultural production methods. Macrotunnel crops include flowers, tomatoes, blueberries, and raspberries. Two separate macrotunnel systems, both with raspberries as the resident specialty crop, were used for the entirety of this project.

Despite the increased use of macrotunnels, guidance to help macrotunnel growers choose management practices that limit agricultural pollutant loads in stormwater-induced runoff is sparse. According to a survey of macrotunnel growers, 61.5 percent of respondents stated they experienced stormwater runoff at their operations and an average of 82 percent indicated they had to contend with stormwater-related operational issues including too wet soil, visible runoff, and enhanced weed growth. When asked about barriers to adoption, 47 percent cited cost, 20 percent cited lack of laborers, and 20 percent stated lack of familiarity with practices. Only 7 percent indicated that it was not their responsibility (for example, due to lease arrangements), indicating a majority of respondents felt a responsibility to accept the burden of implementation.

Given this information, this project sought to evaluate whether four agricultural best management practices (BMP's) commonly used for soil conservation and pollution prevention in open-field crops might help macrotunnel growers cost-effectively reduce their environmental impacts.

The four BMP's (or treatments) studied included a barley cover crop, hardwood mulch, synthetic weed barrier, and polyacrylamide. Five post rows (each of the four treatments plus a control) constituted a treated block. Each block was triplicated at each study site and there were two study sites, one in Santa Barbara County, California and one in Ventura County, California. Runoff samples from each of the treatments were analyzed and statistically compared to runoff samples from the untreated controls with the goal of assessing treatments for their ability to reduce specific environmental pollutants, namely total nitrogen (TN), total phosphorus (TP), and turbidity (or sediment loading measured as NTU).

To complement surface runoff samples, subsurface samples were also collected. Lysimeters of two different lengths (20 cm and 60 cm) were placed in post-rows and samples were analyzed for nitrate. The purpose for this was to study whether treatments exhibited an effect on subsurface (soil) nitrate. In many areas, especially those with shallow water tables, subsurface nitrate can impact water quality.

The use of macrotunnels to grow specialty crops is a lucrative agronomic approach and, as such, it is rapidly expanding throughout California's Central Coast region. In macrotunnel production, crops are grown under

plastic-covered structures to enhance crop performance and to protect crop quality. During rain events, however, these plastic covers intercept and channel storm water flows into post rows, enhancing soil erosion and surface runoff which may degrade surface water quality.

Unfortunately, increased use of these systems comes at a time when climate-induced weather pattern changes, particularly shorter-duration, higher-frequency storm events, are the new norm. Expansion of these system is also occurring while the Central Coast region is grappling with how to assist growers who wish to help address surface and groundwater quality issues. Currently, the United States Department of Agriculture (USDA)- Environmental Quality Incentives Program (EQIP) issues stormwater guidance for single macrotunnel systems under 2,178 square feet, a size which is far less than the acreage typical for Central Coast macrotunnel systems.

This project was important because the study results will help growers better understand the magnitude of macrotunnel environmental impacts while simultaneously evaluating the effectiveness and cost of implementing BMP's designed to address those impacts.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Site Selection:
Initial activities included coordinating partner communication for sample collection and sample analysis, purchasing project supplies, and coordinating with project participants to select study sites and install sampling equipment. In anticipation of rain events in year one, two sites were selected, a 66-acre total (4-acre study plot, well-drained loam, 2 to 9 percent slope) in Somis, Ventura County and a 75-acre total (3-acre study plot, well-drained sandy loam 0 to 2 percent slope) in Santa Maria, Santa Barbara County.

The grant was awarded in October 2015 but neither study site was ready for planting until June 2016 (Somis) and September 2016 (Santa Maria), which was too late for sampling during the 2015-2016 rainy season. Despite this, the macrotunnels, plantings, treatments, and sampling equipment were all in place for the 2016-2017 and 2017-2018 rainy seasons, allowing the project to capture samples from 22 rain events which yielded 28 sample sets due to both "first flush" and "grab" samples being collected during longer or more intense rain events. In total, 420 discrete samples were collected and analyzed for the pollutants of interest, TN, TP, and NTU. The total number of analyzed samples was approximately 1/3 greater (numbering about 600 total analyzed samples) due to replicates, duplicates, and sample spikes.

Runoff from the Somis site was extensive during even low intensity rainfall events, as was expected given the slope. Interestingly, despite the relatively flat terrain and sandy soil of the Santa Maria site, even low intensity rainfall events (some as low as 0.1 inch total rain) provided volumes sufficient to generate "first flush" samples for collection (but not "grab" samples).

There are several general considerations to bear in mind if a similar study is to be undertaken. The first is that gopher holes were commonly observed within macrotunnel post-rows. On several occasions, these holes were so prevalent that they became sinkholes and, eventually, turned into subterranean gullies that funneled stormwater flows under the adjacent raspberry bed and out of the post row. When this happens, the damage

done by these gullies become very difficult to reverse. For that reason, it is advised that post-rows be surveyed for damage regularly and all gopher holes and tunnels be filled as soon as possible.

A second general consideration is that, under high flow conditions, sampling equipment can get damaged, undermined, and/or buried. For example, flooding was often noted where individual post-row outflows combine with other upstream post-row outflows. It was commonly observed that 10-20 feet of the outflow side of treated post-rows would be covered by several inches of sediment brought down with upstream flows. Therefore, to maintain sample integrity, care must be taken to place sampling equipment away from where flooding and sediment deposition might occur.

Finally, it was very difficult to predict the start, intensity, and duration of rainfall events because they often vary according to site-specific conditions. For example, rain events at the Somis project site would occur when it wasn't raining elsewhere, presumably because of orographic lifting (the site was within a steeply sided canyon). In response to these concerns, a prototype sampler was built and tested for this study (a description of the sampler is provided in the Lessons Learned section of this report). To avoid missing first flush events due to mistimed sampling, it is advised that some type of automated sampler be used to capture these samples.

Treatment Lessons Learned:
Treatment establishment was a primary focus early in the project because there were no prior studies to review for guidance. Of primary concern was that the tunnel rows where the treatments were to be placed had vertical posts along their entire length (250-300 feet) and they were only 4.5-5 feet wide, meaning that use of mechanized transport (tractors, etc.) was limited.
Given this, guidance concerning how treatments were established and maintained in these macrotunnel systems over the course of the project is provided below:

- Barley was chosen as a cover crop because of its relatively short stature (to not interfere with laborers) and it was left over seed from a prior University of California Cooperative Extension (UCCE) trial. For the first application in the spring, barley seed was hand sown (600 pound/acre) and lightly raked into the soil. The crop was allowed to grow until it reached the boot/head stage, whereupon it was mowed down using a gas-powered weed trimmer. Mowing also helped control weeds, as did thick, dense stands (whereas weak barley stands increased weed density).

  Care must be taken that the laborers do not mistake cover crop treatments for weeds. In some isolated cases, it was noted that barley treated post rows had evidence of spraying, perhaps due to a new crew member not knowing to avoid spraying.

  Another observation is that stormwater tends to preferentially flow on one side of post rows (the down slope side) which is where the cover crop will grow. Thus, to save seed (and money) when seeding a cover crop, seed on the wet side of the post row, where the cover crop will grow, not the dry side.

- Hardwood mulch was sourced from two separate facilities because the two project sites were too far apart to supply from a single source. In both cases, mulch was delivered to a specified, central area on-site and then delivered to the post rows using a tractor-pulled high-sided trailer. This was done after bed-up but before post placement so that the tractor could drive the length of the post-row unimpeded.

Mulch was a labor-intensive practice, typically involving five people: a single driver, two people pushing mulch off the trailer, and two people spreading mulch within the post-row (2-3" depth). If a mechanized spreader could be used, that would save significant labor costs. Additionally, if mulch can be delivered in the Fall/Winter, when it is cheapest (in some cases free), this will also significantly reduce costs.

Using a chunkier hardwood (rather than finer greenwaste) seems best due to the higher C:N ratio of the former. In either case, it was observed that the mulch would move during heavy stormwater flows so redistribution (or refreshing in thinned areas) may be needed after heavy rains. Maintaining a 2.5-3" mulch layer was needed to control annual weeds.

Another observation for mulch-treated postrows was that they hosted an unusually high density of raspberry shoots and perennial weeds, presumably because of their high soil moisture content, which may require additional labor (hoeing or herbicide treatment) to control.

- For the fabric treatment, a 2.5' wide standard synthetic weed barrier fabric was unrolled in two overlapping strips down the length of the post-row and pinned in place using standard U-staples. In Somis, the weed barrier was laid down after the posts had been put in place whereas, in Santa Maria, the weed barrier was put in before the posts. In retrospect, putting the fabric in place before the posts worked better; it was easier to lay and pin and the fabric did not complicate putting in the posts (there was concern it might jam or twist as the posts were driven into the ground).

  While the weed barrier (fabric) had almost 100 percent effective weed control, there are two caveats. The first is that weeds still grew at the edges where there was bare soil and anywhere there was a hole in the fabric. The second caveat is that, with nothing to retain it, any material deposited onto the fabric was free to run off during rain events. Over the course of the dry season, significant amounts of raspberry debris (discarded fruit, leaves, prunings, etc.) and soil accumulated on top of the fabric. Thus, if weed barrier fabric is to be used, care should be taken year-round to keep the surface of the fabric clean and free of material that might then be subject to runoff in the rainy season.

  At the end of the study, the weed barrier was retrieved, demonstrating its reusability. While both the application and retrieval was done by hand, it is likely that mechanical application and retrieval using a tractor (similar to how drip line is managed in row crops) would be more cost effective.

- Polyacrylamide (PAM) was purchased in standard powder form and dissolved in water for use as a solution. Concentrated PAM solutions (40 parts per million (ppm)) were made in one gallon jugs and then poured into four gallon backpack sprayers and diluted with three gallons of water (for a final concentration of 10 ppm). This 10 ppm solution of PAM was remarkably viscous and difficult to apply using a standard backpack sprayer. It did not disperse as a spray, it came out as a stream, and it was physically tiring maintaining the pressure needed to apply it.

  Because of the difficulties applying PAM in solution form, later applications were done using the powder form. Specifically, salt-shaker-like applicators were made so that PAM could be shaken out by hand over the length of the post row. Given the fine-size, low density, and exceptionally low application rate of PAM (0.15 lb/post row), this approach appeared the most appropriate and, in fact,

seemed to work well. A fuller description of these applicators can be found in the Lessons Learned section of this report.

While PAM is very effective at reducing turbidity, care must be taken to ensure its effectiveness when used in macrotunnels. PAM reduces soil loss by binding soil particles together at the soil surface. Avoid disturbances to this crust (for example, people walking on it) and restore this crust by re-applying PAM after heavy rainfall. Finally, it is most effective when applied when the soil is moist and immediately prior to rainfall events.

Sample Collection and Data Analysis:
First-flush runoff samples (the volume collected at the start of rainfall events) were collected in clean 500 mL Nalgene bottles and grab-samples (volumes collected at hour intervals after the first flush sample was collected) were collected in 250 mL Nalgene bottles. This approach yielded 420 field samples and well over 600 analysis samples (field duplicates, field blanks, etc.) from 22 sampling events and 28 sample sets (first flush plus grab samples).

All samples were stored in shipping coolers and transported to the UCCE facility for subsampling. Subsamples were analyzed for turbidity, a measured of suspended solids, using a WQ770-B Turbidity Meter (Global Water Instruments, Gold River, CA 95670). These subsamples were then refrigerated on-site as back-up and/or for random analysis by an independent, third-party lab.

All remaining samples were shipped to the University of California, Riverside in styrofoam shipping containers (with ice packs) for TN and TP analysis using next-day service. Samples were not filtered and not acidified as the digestion/analysis methodology chosen required unfiltered, neutral pH water samples. The digestion method used was 4500-P J. Persulfate Method for Simultaneous Determination of TN and TP (Standard Methods, 2002) and the analysis instrument was a Discrete Analyzer AQ2 (Seal Analytical Inc., Mequon, WI). Standard Operating Procedures (SOPs) (Green, 2006) were followed.

Education and Outreach:
Project activities included a variety of outreach and education events. Initial activities involved development of a macrotunnel grower survey which was disseminated at a grower meeting and an outreach meeting in Ventura County as well as through the email lists of project partners (Ventura County Resource Conservation District (VRCD), UCCE, and Reiter Affiliated Companies) and professional partners (Farm Bureau of Ventura County and the Ventura County Irrigated Lands Group). Results from this survey were used to determine current stormwater practice use and assess the likelihood of future use of project treatments.

Subsequent education and outreach events included project presentations at agriculturally focused events hosted by the American Society for Horticultural Science (ASHS), the North American Raspberry and Blackberry Association, and the Central Coast Water Board.

In coordination with the poster presentation at the ASHS conference, conference attendees also participated in a tour demonstrating the project treatments at the UCCE Hansen Research Center (HRC). Separately, project partners hosted a project outreach event at HRC to present final project results to Ventura County-based growers and a second outreach event is planned in late September for Santa Barbara-based growers.

Preliminary project results have been published in a supplemental to *HortScience*, the peer-reviewed journal of ASHS and a full article was submitted for publication (October 2018) through the California Association of Pest Control Advisers (CAPCA) magazine, Adviser, to coincide with the CAPCA 2018 annual conference. Finally, a full research article is expected to be submitted to California Agriculture, the quarterly, peer-reviewed journal of the University of California Division of Agriculture and Natural Resources.

The scope of this project involved assessing the effectiveness of treatments on stormwater control from macrotunnel production systems. Because of the nature of macrotunnel production systems, these types of structures are predominately associated with specialty crops. This project evaluated treatment effectiveness within macrotunnel production systems for a specific specialty crop, raspberries.

Although the treatments evaluated for macrotunnel stormwater control are not unique to specialty crops, data concerning treatment effectiveness in macrotunnels does not necessarily extend to other production systems. Thus, while the results of this study may be generally applicable to other commodities, this project did not result in any enhancement in the competitiveness of non-specialty crop commodities.

The application of this study's results, however, are expected to enhance the competitiveness of macrotunnel-grown specialty crops. Specifically, results from this study clearly indicated differences in the effectiveness of treatments in addressing the runoff of sediment and phosphorus (and, by extension, other soil-borne pollutants) as well as the leaching of nitrate. In areas where the macrotunnel specialty crop industry may be facing environmental regulations, the use of these treatment practices may, therefore, allow these operations to avoid environmental violations while maintaining production targets.

Both the Santa Maria Site Coordinator (SMSC) and the Ventura Site Coordinator (VSC) assisted with project site maintenance, sampling equipment emplacement, maintenance, and replacement, project site coordination, project sampling/shipping, data collection/filing/analysis, supply purchasing, macrotunnel grower survey development/deployment, and outreach/education coordination and material development. The SMSC and VSC, along with other personnel, would often be deployed to both sites simultaneously to help the other collect samples, despite there being site-specific personnel designations, because the random timing of rain events and the difficulty in sampling when only a single individual was on-site required multiple personnel be available.

The Ventura Fiscal Director (VFD) activities were entirely focused on invoicing and reporting. All purchase invoices as well as all project partner work invoices were handled by the VFD. The VFD also handled all RCD-related payroll issues and questions, participated in providing information requests from project partners, and participated in reviewing information regarding project-related activities and modifications to the project and cooperative agreements between the RCD and CDFA, UCCE, and UCR.

Cooperative Extension Staff Research Analyst (CESRA) and Cooperative Extension Researchers (CER's) participated in equipment storage and site maintenance, project site coordination, sample collection/shipping, cost assessments, weed counts, turbidity assessments, cost-benefit records keeping, and general project coordination. They also provided preliminary assessments of project results and participated in outreach/education events discussing project results.

Environmental Analysis Staff Research Analyst (EASRA) analyzed all field samples for TN and TP, provided all partners updated TN and TP data tables, contributed towards data assessments, and worked with the CESRA, CER, and SMSC to draft project findings for outreach/publication purposes.

Cost Analysis Staff Research Associate (CASRA) coordinated with all project partners to collect treatment cost estimates and then analyzed the treatment cost information provided to estimate project-related treatment cost benefits for outreach/publication purposes.

Goals and Outcomes Achieved

This project's primary measurable outcome was an increase in the number of macrotunnel specialty crop growers using the stormwater control practices funded for evaluation. The primary set of activities associated with this measurable outcome involved establishing macrotunnel research plots to quantify the environmental and economic impacts of stormwater control practices and communicating those findings to specialty crop stakeholders through outreach and education.

As discussed in the Project Summary and Project Approach sections of this report, two macrotunnel research plots were successfully established, each of the approved stormwater control practices were emplaced within post-rows of raspberry macrotunnels, and stormwater runoff samples were collected and analyzed for the approved environmental pollutants over the 2016-2017 and 2017-2018 rainy seasons.

Results from this study have been presented to audiences of macrotunnel growers, caneberry production groups, berry industry professionals, and environmental professionals through project outreach events, professional meetings, and research briefings. Quantitative information regarding the environmental benefits of stormwater practices on turbidity, nitrogen, and phosphorus loads was presented along with their associated economic benefits.

Given the fact that performance measures, benchmarks, and targets were largely met by this project, it is expected that the expected outcome, namely an increase in the use of post-row macrotunnel stormwater control practices will result. Based upon feedback from outreach participants and grower-partners, indications are that the single greatest increase will be in the use of weed barrier fabric by organic certified macrotunnel operations.

All outcome measures were expected to be achieved during the project but late-season rains delayed final sample analysis and data set assessment. Thus, while the majority of set targets such as TN, TP, turbidity, grower surveys, economic assessments, and outreach events were met, practice-adoption outcome measures and publication measures were delayed until the end of the grant period. Consequently, these outcome measures are still on-going and expected to be achieved beyond the project timeframe. Thus, the only outstanding target is the publication of study results in a peer-reviewed journal. This article, together with additional, non-peer reviewed articles, will be submitted following the project terms.

This project was accomplished in partnership with Reiter Affiliated Growers, the region’s largest caneberry grower group. Group representatives have expressed keen interest in study results presented at the Ventura County outreach event (June 2018) and have asked that a second presentation for growers be scheduled. Caneberry macrotunnel operations in Santa Barbara, California reach peak activity between June and September, therefore outreach occurred in October 2018.

Environmental Impact Targets-Turbidity:
Targets for environmental impacts included turbidity reductions of 50 percent for treatments versus untreated controls. As illustrated in Table 1, turbidity, which is a measure of suspended material and a common indicator of water quality impacts, was reduced significantly by all four treatments studied (barley cover crop, weed barrier fabric, hardwood mulch, PAM) at both project sites (Santa Maria in Santa Barbara County and Somis in Ventura County).

Table 1: Turbidity (NTU) measurements of treated and untreated project post-rows.

Turbidity (NTU)				
Santa Maria			Somis	
Treatment	**Mean**		**Treatment**	**Mean**
Barley	*426.1*		Barley	*284.0*
Fabric	*253.7*		Fabric	*199.2*
Mulch	*394.3*		Mulch	*115.3*
PAM	*210.7*		PAM	*202.1*
Untreated	2360.3		Untreated	1190.8

Italicized numbers indicate significant differences between the treatments and the untreated control at the P=0.05 level.
The values presented are averages of all the corresponding treatment samples analyzed over the course of the project.

Environmental Impact Targets: Total Nitrogen:
In addition to turbidity, targets for environmental impacts included a 50 percent reduction in nutrients in surface runoff, specifically TN and TP. As shown in Table 2a, both the barley and the PAM treatments showed an increase in the concentration of TN, although the increases were not statistically significant. The fabric treatment reduced TN in Santa Maria but showed a statistically significant increase at the Somis project site. Finally, for the mulch treatment, there was an increase in TN in Santa Maria but a statistically significant decrease in Somis.

Based upon this data, these treatments are limited in their ability to reduce TN concentrations in runoff. There are three important considerations, however. The first is that, based on the runoff concentrations measured, all post-row samples were below drinking water quality thresholds for nitrate (i.e., 10 mg/L Nitrogen). This is likely to do with the fact that post-rows are not fertilized (unlike the raspberry beds under the plastic) and, therefore, there isn't much nitrogen in the post-rows.

The second consideration is that barley growth in Santa Maria was decidedly different from that in Somis. Santa Maria barley stands were sparse and patchy compared to those in Somis. Similarly, the mulch quality differed between sites (the Santa Maria mulch was finer and more greenwaste-based than the Somis mulch). These observed treatment differences are suspected to have contributed to the notable differences in treatment effectiveness between the two sites (i.e., these two treatments in Santa Maria were markedly less effective than those same two treatments in Somis for all parameters studied).

The third consideration is that, based on differences in treated versus untreated post-row runoff volumes (Table 5), the nitrogen mass in treatment runoff may be less than that of the untreated controls, implying that the treatments may, indeed, reduce water quality impacts from TN.

For example, runoff volumes for barley in Santa Maria was 27.8 percent less than that for the untreated control. This implies that the actual mass of nitrogen delivered as runoff from a barley treated post-row would be 27.8 percent less than that of an untreated post-row. Using the values presented in Table 2a and Table 5, then, the TN concentrations of the Santa Maria barley and mulch treatments would be reduced below that of the untreated control (i.e., 3.39 and 4.02 versus 4.06 mg N/L, respectively). These adjusted TN concentrations are provided in Table 2b.

Table 2a: Total Nitrogen (TN) concentrations of treated and untreated project post-rows.

Total Nitrogen (mg N/L)				
Santa Maria			Somis	
Treatment	**Mean**		**Treatment**	**Mean**
Barley	4.69		Barley	3.20
Fabric	2.78		Fabric	*5.07*
Mulch	5.55		Mulch	*1.67*
PAM	8.02		PAM	3.28
Untreated	4.06		Untreated	3.16

Italicized numbers indicate significant differences between the treatments and the untreated control at the P=0.05 level.
The values presented are averages of all the corresponding treatment samples analyzed over the course of the project.

Table 2b: Total Nitrogen (TN) concentrations adjusted for flow in treated and untreated post-rows.

Adjusted TN concentration (mg N/L)				
Santa Maria			Somis	
Treatment	**Mean**		**Treatment**	**Mean**
Barley	3.39		Barley	1.08
Fabric	2.67		Fabric	6.24
Mulch	4.02		Mulch	0.68
PAM	7.84		PAM	3.07
Untreated	4.06		Untreated	3.16

To summarize, none of the treatments studied demonstrated the ability to achieve a 50 percent reduction in surface runoff TN concentrations although levels less than controls were noted in Santa Maria (barley) and Somis (mulch)(Table 2a).

In terms of TN mass, adjusted concentrations (Table 2b) show that, in Somis, barley and mulch treatments were capable of achieving a 50 percent reduction versus controls. Furthermore, in Santa Maria, barley, fabric, and mulch treatments reduced TN mass below that of the controls, as did PAM in Somis. In contrast, adjusted TN concentrations for PAM (Santa Maria) and fabric (Somis) exceeded the controls.

Implicit in the previous discussion is the idea that surface runoff flow volumes were not the same for all treatments, particularly under low intensity rainfall events. Specifically, the barley and mulch treatments appeared to increase water infiltration which, presumably, reduced TN mass by leaching a fraction of the available nitrogen into the soil. Once in the soil, that nitrogen might get leached below the root zone or become available for uptake (raspberry's, weeds, barley, fungi, etc.).

To study the treatment effects on this subsurface (soil) nitrogen pool, the soil solution was sampled using lysimeters. As shown in Table 3, both project sites had lysimeters but only the 20 cm long (8-inch sampling depth) lysimeters were present at both sites. Comparisons of the data from these 20 cm lysimeters shows that all treatments reduced subsurface nitrate concentrations below that of the controls, although not all reductions were statistically significant. Furthermore, the barley treatment reduced subsurface nitrate levels by over 50 percent as did fabric (Santa Maria), all of which were statistically significant.

Looking at the 60 cm long lysimeters (18" sampling depth), barley and mulch both reduced nitrate levels by 50 percent compared to controls whereas the fabric and PAM concentrations increased by between 160 to 340 percent. It is interesting to note that the trends observed for the fabric and PAM subsurface nitrate data mirrors that observed in the fabric and PAM surface runoff data. This implies that further study of the relationship between post-row stormwater flows and their role in affecting the distribution of nitrogen between surface runoff pools and subsurface leachate pools is warranted.

Table 3: Subsurface Nitrate concentrations for treated and untreated project post-rows.

Nitrate (mEq/L)							
Santa Maria			Somis			Somis	
20 cm depth			20 cm depth			60 cm depth	
Treatment	**Mean**		**Treatment**	**Mean**		**Treatment**	**Mean**
Barley	*5.35*		Barley	*1.85*		Barley	*3.45*
Fabric	*7.42*		Fabric	10.70		Fabric	*13.52*
Mulch	*10.37*		Mulch	9.72		Mulch	*2.68*
PAM	13.96		PAM	14.49		PAM	*28.10*
Untreated	17.53		Untreated	15.75		Untreated	8.35

Italicized numbers indicate significant differences between the treatments and the untreated control at the P=0.05 level.
The values presented are averages of all the corresponding treatment samples analyzed over the course of the project.
20 cm and 60 cm depths refer to the length of the lysimeter and correspond to approximately 8" and 24" sampling depths.

Environmental Impact Targets-Total Phosphorus:
With respect to phosphorus (Table 4), in Somis, all treatments significantly reduced the concentration of TP in runoff samples compared to controls and, additionally, well below the 50 percent reduction target. In Santa Maria, however, increased concentrations were measured for the barley and mulch treatments, while decreased concentrations were noted in the fabric and PAM treatments.

Again, however, as noted in the discussion for TN, adjusting these concentrations by their corresponding runoff volume reductions implies the total mass of phosphorus exported in surface runoff per storm event for both the barley and mulch treatments in Santa Maria is less than that for untreated controls. Thus, these treatments may, in fact, reduce TP-related water quality impacts.

Table 4: Total Phosphorus (TP) concentrations of treated and untreated project post-rows.

Total Phosphorus (mg P/L)				
Santa Maria			Somis	
Treatment	**Mean**		**Treatment**	**Mean**
Barley	7.10		Barley	*3.91*
Fabric	4.30		Fabric	*2.78*
Mulch	5.44		Mulch	*3.30*
PAM	3.57		PAM	*2.23*
Untreated	5.39		Untreated	9.41

Italicized numbers indicate significant differences between the treatments and the untreated control at the P=0.05 level.
The values presented are averages of all the corresponding treatment samples analyzed over the course of the project.

Table 5: Runoff volumes (Gallon) measurements of treated and untreated project post-rows.

Runoff Volume (Gallon)				
Santa Maria			Somis	
Treatment	**Mean**		**Treatment**	**Mean**
Barley	*3.14*		Barley	*1.33*
Fabric	4.18		Fabric	*4.92*
Mulch	*3.15*		Mulch	*1.63*
PAM	4.25		PAM	3.75
Untreated	4.35		Untreated	4.00

Italicized numbers indicate significant differences between the treatments and the untreated control at the P=0.05 level.
The values presented are averages of all the corresponding treatment samples analyzed over the course of the project.

Communications Target: Bare Soil Post Row Use:
The set target was a 20 percent reduction in bare soil post row use. Based on survey responses indicating an interest in trying these practices, combined with the strong interest in study results from both industry partners and the Central Coast Waterboard, this set target is likely to be achieved in the near-term.

For example, when presented with a question regarding their use of stormwater control practices, respondents indicated the following adoption rates: cover crop (21 percent), fabric weed barrier (44 percent), mulch (19 percent), and PAM (13 percent). When asked to rate their interest in implementing stormwater control practices, 53 percent of respondents indicated an interest in cover crops, 65 percent for fabric weed barrier, 53 percent for mulch, and 59 percent for PAM.

Based upon discussions with industry partners, and as indicated by the high interest in fabric weed barrier, the most likely early-adopters are organic-certified operations or those pursuing organic certification. These operations have few choices other than weed barriers for weed control since herbicide use is prohibited.

Communications Target: Management Practice Publications:
There were two set communications targets, a single management practice publication in a trade/industry publication and a single peer-reviewed journal submission. Preliminary study results were compiled and presented before two industry bodies, the American Society for Horticultural Science (2017 ASHS

conference) and the North American Raspberry and Blackberry Association (NARBA) (2018 NARBA conference).

An abstract for the poster (board #070) presented at the 2017 ASHS conference was published in Supplement to HortScience, Volume 52(9), page S390.

A poster was presented at the 2018 NARBA conference and conference proceedings included a visit to a macrotunnel exhibit hosted by UCCE project partners where project treatments were exhibited. An excerpt from this conference has not yet been published by NARBA but conference material is available on their conference webpage.

An abstract concerning the efficacy of treatments for weed control and nutrient management was submitted for publication in the October 2018 conference edition of the CAPCA magazine, *Adviser*. (See additional information section).

Finally, project partners will use feedback from the above conferences and publication editors to streamline publication in a peer-reviewed journal. Currently, partners have committed to publishing a research article in an upcoming edition of the peer-reviewed journal *California Agriculture*. *California Agriculture* is published quarterly by the University of California, Division of Agriculture and Natural Resources, and topics focus on agricultural, natural, and human resources.

Economic Impact Target: Operational Cost Reduction:
The target set for economic impact was a 50 percent cost reduction over standard practices, primarily by avoidance of regulatory burdens, reductions in weeding costs, and reductions in labor and production costs associated with addressing on-site runoff issues. These targets are discussed separately in the relevant sections below.

Regulatory Cost Reductions:
Environmental quality in Ventura County and Santa Barbara County is monitored by their respective Regional Water Quality Control Boards. Both counties are subject to Conditional Waivers which define water quality goals, pollution thresholds, and regulatory mechanisms designed to protect water quality. This information helps agricultural operations decide how to best reduce their environmental impacts and comply with the goals of the Conditional Waiver.

Agricultural operations within the areas subject to Conditional Waivers pay a fee as part of their compliance. In Santa Barbara this fee is estimated to be $80 per acre a year. In Ventura County, the fee is estimated at $20 per acre a year. If growers were subject to individual discharge permits, the costs of complying with Water Quality Control Board regulations is estimated to be no less than $1,000 per operation on average.

The estimated treatment costs provided in Table 6 are similar to the costs of complying with the Conditional Waiver, particularly in the Central Coast. Furthermore, cost estimates for each of the treatments studied are all far less than the individual discharge permit costs implying that if/when growers have to individually demonstrate adoption of stormwater pollutant discharge practices, any of these treatments would help mitigate the compliance costs.

Weeding Cost Reductions:
Standard weeding costs were estimated at $250 per tunnel cycle-per acre. Comparing this value to those presented in Table 6, barley offers no cost benefits, fabric offers a 7.6 percent cost reduction, mulch achieves 59 percent cost reduction, and PAM provides a 23 percent cost reduction. Thus, mulch was the sole treatment estimated to achieve the targeted 50 percent reduction in weed costs.

On-Site Runoff Cost Reductions:
Costs associated with addressing on-site runoff issues was estimated at $300 per tunnel cycle-per acre. It was assumed that these costs would be 20 percent higher than the estimated weeding costs because of the need for machinery and higher paid machinery operators. Sediment reduction values (i.e., turbidity, Table 1) ranged from 80 to 90 percent in Santa Maria to 76 to 90 percent in Somis. Thus, all treatments are estimated to have exceeded the 50 percent sediment management cost reduction target.

Treatment Cost Implementation Estimates:
The actual estimated costs of implementing the different treatments studied in this project are presented in Table 6. These estimated costs reflect charges associated with the implementation and management of the practices along with savings estimates associated with reduced labor/machinery operations and other relevant cost savings.

Table 6: Treatments and their associated implementation costs.

Treatment	Costs/Tunnel Cycle/ Post Row	Costs/Tunnel Cycle/ Acre	Costs/Acre/Year
Barley	$46.45	$255.45	$85.15
Fabric	$42.06	$231.32	$77.11
Mulch	$18.74	$103.10	$34.37
PAM	$34.96	$192.27	$64.09

Post Row Treatment Area = 1800 ft², 5.5 post rows = Treated Acre, Tunnel Cycle = 3 crop seasons

Major successful outcomes from this project included:

- Significant reductions in turbidity (50 percent or greater for all treatments) and potential reductions in associated soil-borne pollutant loads including TN and TP;
- Data suggested that runoff from macrotunnels may not exceed drinking water thresholds for TN, thereby alleviating some of the concerns related to macrotunnel nitrogen pollution risks;
- Substantial interest from industry partners included Reiter Affiliated Growers and environmental quality partners, especially relating to subsurface nitrogen risks;
- Data indicated that operational costs and associated cost reductions related to treatment implementation were substantial and offered credible strategies if stormwater-related regulatory penalties are levied.

Beneficiaries

Reiter Affiliated Growers, the industry-leading caneberry producer (and macrotunnel grower) in the Central Coast benefited directly because their growers were project participants and a relatively high proportion of their staff attended project outreach events.

The Farm Bureau of Ventura County, the Natural Resources Conservation service, and the Ventura County Irrigated Lands Group staff and associated growers benefited due to the presentation of research results to these organizations during outreach events.

The American Society for Horticultural Science (ASHS), the North American Raspberry and Blackberry Association, and the Central Coast Water Board staff, associated growers, scientists/researchers, students, and agricultural and environmental professionals benefited from study results presented at meetings and conferences.

There were approximately 150 attendees at the September 2017 American Society for Horticultural Science conference (ASHS) conference session where preliminary project research was presented. Based on direct conversations with participants, it is estimated that 30 people benefited directly from this project. This particular poster session included plasticulture (macrotunnel) specific topics, indicating the audience was particularly receptive to this information, and participants ranged from horticultural scientists/professionals to students involved in macrotunnel production and research.

There were approximately 250 attendees at the NARBA conference which included caneberry growers, researchers, marketers, and caneberry industry professionals. Based on direct communication with conference attendees during the poster presentation sessions, it is estimated that 25 people benefited directly from the project findings. Since the project and associated research treatments were also demonstrated at the UCCE HRC in coordination with the February 2018 NARBA conference, it is expected that all 250 participants benefited.

There were 84 attendees at the Central Coast Regional Water Board May meeting, including Water Board staff and representatives from various agriculturally relevant grower, trader, industry, and environmental groups. More broadly, this group represents approximately 1,800 growers and farming operations. An estimated 5 percent of these growers (90) are associated directly with macrotunnel caneberry production and would be expected to benefit directly from this information. However, the material presented by project participants concerning subsurface nitrate monitoring is certainly expected to help significantly more Central Coast growers attain the water quality results sought by the Central Coast Water Board.

There were 65 attendees at the final project outreach event hosted by UCCE at the Hansen Agricultural Center in June 2018, including macro tunnel growers, land owners, and local Water District staff and a similar amount (60) attended the October meeting in Santa Barbara County. Reiter Affiliated Companies (RAC), the industry-leading caneberry producer (and macrotunnel grower) in the Central Coast benefited directly because their growers were project participants.

More broadly, since RAC is the largest fresh, multi-berry producer in the world and the leading supplier of fresh strawberries, raspberries, blueberries and blackberries in all of North America, study results are likely to provide wide-ranging economic benefits to their field operations. An estimate of this national and global audience size and the associated economic benefit is not available, however.

Lessons Learned

One of the most positive developments of this study was the fact that TN concentrations measured in post-row runoff samples were lower than expected. This suggests that macrotunnel production systems may not be contributing as much TN as previously assumed.

On the other hand, turbidity data clearly demonstrated that macrotunnel production systems are a source of sediment and sediment associated pollutants, phosphorus specifically. As discussed in the Goals and Outcomes Achieved section of this report, however, the treatments studied were able to significantly and substantially reduce turbidity.

Several generalized lessons were learned with respect to site selection and project implementation, and the reader is encouraged to review the Project Summary and Project Approach sections for a fuller explanation.

A tangible product of this study that may be useful for future studies was the development of a low-cost automated sampler. This product was developed to address concerns that rainfall might occur prior to a person arriving onsite to sample. While automated samplers can be purchased, it was felt that fashioning a low-cost, back-up prototype would benefit not only this, but future studies.

To that end, 500 mL square Nalgene bottles were converted into passive samplers by drilling two holes into opposite sides of the bottle lid and threading plastic tubing in through one of the holes. Waterproof labels were affixed to the bottle side adjacent to the tube and standard Velcro was affixed to the bottle side adjacent to the open hole (see picture 1).

Picture 1: Passive sampler

Picture 2: Sampler in receptacle

Picture 3: Complete unit

As shown in picture 2, a labelled sampler could then be placed at the bottom of a stormwater receptacle, in this case, a standard five gallon bucket. The sampler is held in place by another Velcro patch adhered to the receptacle. It was found that standard Velcro adhesive was sufficient to hold both patches in place and that the use of additional adhesives, for example epoxies, led to a weaker mount.

As the receptacle fills with water, so too will the sampler. However, as water flows into the hole drilled into the sampler lid on the Velcro side (closest to the receptacle bottom), it must displace air. This is the role of the plastic "snorkel" tube. Care must be taken that the end of the tube be placed above the sampler and protected from kinking and plugging so air can evacuate freely. The project staff found it convenient to thread the end of the tube through a hole drilled into the receptacle cover (pictures 1 and 3) which protected and identified the assembly.

Also, to ensure complete filling, the tube should not be inserted more than about ½" into the bottle. Once the sampler fills with sample, it will resist further water intrusion, thereby delivering a representative first flush sample. Upon removal from the receptacle, the drilled cap is replaced by an undrilled cap and the entire bottle is ready for storage or shipping.

Another tangible product developed during this project was a hand applicator for PAM dispersal. Applying solubilized PAM was difficult - PAM was difficult to dissolve, the solution was viscous, and standard sprayers were prone to plugging.

Applying PAM in its powder form was simpler except that its texture, density, and low application rate of 10 ppm (equal to about 0.15 lb/post row) precluded the use of standard applicators. To address this, powder applicators were made from 250 ml Nalgene bottles - holes were drilled into the Nalgene lid, 0.15 lb PAM was weighed into the Nalgene, and the powder was shaken out over the entirety of the post row.

Almost all outcome measures were achieved by this project. To summarize, target reductions for turbidity, TN, and TP were achieved by all or by subsets of all treatments studied. Additionally, target reductions in treatment implementation costs over standard practices were achieved by a subset of the treatments. Finally, trade/industry publication targets were also met.

The only outcome measure which was not achieved was the publication of study results in a peer-reviewed journal. This, however, is primarily due to the timing of field-based rainfall events which, of course, cannot be controlled and which is an issue unique to this project. The project staff are anticipating finalizing the draft December 2018 to submit for publication in the Spring of 2019. With possible needed revisions and edits, the final publication is anticipated to be done Fall 2019.

Additional Information

The peer-reviewed journal of ASHS and a full article was submitted for publication (October 2018) through the California Association of Pest Control Advisers (CAPCA) magazine, Adviser:
CAPCA article (October 2018, page 58, 60): https://capca.com/publication/october-2018-adviser-magazine/

A copy of the project-specific VCRCD webpage. This page was used to host project related information:
http://www.vcrcd.org/

USDA Project No.: 37	**Project Title:** Evaluation of Trade-Offs between Winter Cover Crop Production and Soil Water Depletion in San Joaquin Valley Row Crop Fields and Orchards	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB15037	**Date Submitted:** December 2018
Recipient Contact: Jeff Mitchell	**Telephone:** (559) 646-6565	**Email:** jpmitchell@ucdavis.edu

Project Summary

Maintaining the competitive edge that California vegetable farms have achieved over the decades, while simultaneously developing practices that address the many uncertainties of climate change is a major challenge that now requires strategic improvements in how production systems operate. One means for improving the efficiency and productivity of cropping systems while also minimizing adverse environmental impacts that has been used in other regions of the world is the use of cover crops to provide nitrogen (N), store carbon (C), and improve soil function. While a growing body of evidence from these other regions now supports the use of cover crops to provide multiple services to farm systems, current cover crops use in California's annual cropping systems is quite low due to concerns about opportunity costs involved with forgoing cash crop income, the cost and availability of additional water needed to grow a cover crop particularly during periods of drought, and depletion of the soil water reserve by the cover crop. Despite these challenges and potential tradeoffs, a growing number of vegetable crop farmers in California's Central Valley are now actively seeking to integrate cover crops in their systems. They currently lack, however, science-based information related to cover crop management and water use. This project's goal was to provide farm studies to determine the biomass production potential of various winter windows for single and diverse multi-species cover crop mixes, changes in soil water storage under these cover crops compared to fallow, and data on the C and N capture and provision potential of these mixes to inform farmers of the true tradeoffs associated with this practice.

Maintaining the competitiveness of California farms while simultaneously developing practices that address uncertainties of climate change and water shortage is a major challenge that requires strategic improvements in how production systems operate. A well-known means for improving the efficiency and productivity of cropping systems while also minimizing adverse environmental impacts and maintaining soil and water quality is the use of cover crops to provide and capture N, store C, and improve soil function. Current cover crop use in California, however, is low due to concerns about lost opportunity costs involved with forgoing cash crop income, the cost of water needed to grow a cover crop, and depletion of soil water by cover crops. Farmers currently lack science-based information related to cover crop management and water use under the urgent prospect of increased variability of water supplies and frequency of drought. This project will quantify changes in soil water storage and soil water intake rates under cover crops and native vegetation compared to fallow, determine the biomass production potential of various cover crop mixtures, provide data on the C and N capture potential of cover crops, and conduct a cost-benefit analysis for both tomato and almond production systems to inform farmers of the trade-offs associated with this practice.

In recent years, a growing number of San Joaquin Valley farmers who recognize the value of using cover crops, but who are uncertain as to how these benefits are offset by the water use and cost of farming

operations needed to grow a cover crop. In recent years, the largest processing tomato producer in California has become so committed to using cover crops in their San Joaquin Valley production fields that they include them on much of their acreage ahead of their tomatoes even during the California drought seasons. They speculate that the practice on balance provides benefit, but they lack concrete information about the actual water cost of the cover crop. This project aimed to fill these knowledge gaps and inform farmers of the water-use trade-offs associated with cover cropping.

To address the need for info on cover crop water use that has been raised by scores of Central Valley farmers, the project set out to determine soil water depletions for cover crops for different winter growing windows and cover crop selections. This info will provide science-based data to inform decision-making and management. The broader-scale impact or benefit of this work, was to determine if cover crop can be a justifiable practice, to improve the soil health of Central Valley vegetable crop farm fields and the productivity and sustainability of agroecosystems.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The project work plan involved the collection of farm data on soil water content during and at the end of cover cropping in comparison to water content under standard winter fallow. This was done during each winter of the project at several sites throughout California's Central Valley.

The project team generated science-based information in both annual crop fields and in orchard crop environments. The hypothesis was that due to the lower evapotranspiration demand of a winter cover crops, the ability of a cover crops canopy to enhance soil water infiltration and to shade and cool the soil, as well as the value of cover crops in terms of adding C to the soil and thereby increasing soil water holding capacity, that overall water use by cover crops may be lower than assumed relative to the potentially offsetting value provided by the cover crop.

The project research aimed to bridge hydrologic, agronomic, and social sciences to answer questions related to demand-side water management in California. The state's highly manipulated hydrologic regime and unique Mediterranean climate enable agriculture production of over 400 commodities, providing a unique opportunity to study water resource management from the water user perspective. These high value crops incentivize growers to continue production, while also facing diminishing water resources due to increased demands, loss of aquifer storage, and variable precipitation throughout the state. This offers a valuable opportunity to study the adoption of demand-side water management strategies in agricultural production to address the growing challenge of water scarcity.

The interviews revealed site-specific success of winter cover cropping, which is supported in the preliminary economic analysis. This economic model could be further developed to provide decision-making support for growers throughout the Central Valley, or beyond to other crop systems and regions of California. An example of this type of tool has been developed by the United States Department of Agriculture for operations in the Midwest and can serve as a guide to the expected economic returns of an operation. The final products will be applicable and scalable to a diverse mix of operations and may increase the adoption of winter cover crops if our scenario analysis justify water costs associated with growing winter cover crops.

Project driving questions: The project focus was in how water can be managed through biology by quantifying the hydrologic and economic impacts of winter cover crops in processing tomato and almond operations in the Central Valley. The research efforts set to address the following research questions:

1) How do winter cover crops affect agricultural water budgets?
2) How do winter cover crops affect the economic viability of operations?

The research was culminated and summarized into a conceptual model that included the end goal in the middle with concentric shapes that identify each project component and the data collection and modeling efforts for each (Attachment 1 Figure 1).

1) How do winter cover crops affect agricultural water budgets?

The goal of this project component is to understand how winter cover crops affect components of the water budget on farms in the Central Valley from November to March crop season for tomato and almond production systems (Attachment 1 Figure 2). The main hypothesis was that winter cover crops provide an input to agricultural water budgets.

Hydrologic data was collected through collaborations with farmer-partners and experimental farms operated by the University of California (UC), Davis to characterize the hydrologic impact of winter cover crops. Data was collected during a three-year field campaign from 2016-2018. Eleven field sites were established throughout the Central Valley, and a replicable experimental design was implemented at each site, while working within the means of the growers to accommodate the data collection process. On-farm experimental design included a cover cropped area to be compared with a control (bare surface) of at least four acres in row crop fields and at least four rows in almond orchard. Similar data from each treatment was collected from November to March, although measurement frequency varied between sites. The operations cover a broad climate gradient (Attachment 1 Figure 3), represent the diversity of operations within the Central Valley, and operate a typical management system that includes winter cover crops (Attachment 1Figure 4). Data on water budget components as well as agronomic data has so far been collected from October 2016 – June 2018.

Soil samples were collected at each site to determine gravimetric water content using a 5.7-centimeter (cm) (2.25 inch) mud auger. Sampling occurred at the beginning of the field season in early to mid-November and again at the end of season starting in March to June, with the end date varying between field sites. Samples were collected at either four or eight locations in each field, two or four per treatment. Each location was sampled to depths 15, 30, 60, 90, 120 cm. Sample were dried at 105 degrees C for a 24-hour period, after initial wet weight were recorded. Dry weights were determined once the samples maintained a constant weight.

Neutron probes were used throughout the winter season to measure weekly volumetric water content at 30 cm increments up to at most 270 cm below the soil surface. Neutron probes measure soil moisture based on the emission of “fast” neutrons by a radioactive source through radioactive decay. They collided with atoms in surrounding soil and a detector measures low-energy neutrons that lose energy through collision with hydrogen. The result was a count rate of slow neutrons that is proportional to the density of hydrogen atoms near the radioactive source. This count was used to estimate volumetric water content.

A minimum of four neutron probe access tubes were installed in each treatment at each location to characterize water conditions. Neutron probe access tubes were installed using hand augers to minimize soil disturbance and achieve a tight fit to minimize surface water from draining alongside the tube and occurrence of cavities that could influence calibration. A total of 125 PVC tubes were installed and extend below and above the deepest and shallowest depths to minimize influence of soil and humans on the readings, respectively.

Volumetric water content was estimated from neutron probe count rates based on field specific calibration curves that describe the linear relationship between the relative count rate (count rate divided by a standard count) and volumetric water content. Relative count accounts for electronic drift, instability of electronics, and radioactive decay of the neutron source. Counts were taken using a Campbell Scientific 501 Direct Read Hydroprobe (Instrotek, Martinez, California) for each depth using a 16-second measurement period for each reading. A 240-second standard count was made by putting the probe on top of its plastic storage container in an open area adjacent to the field or orchard that was being monitoring and then determining the 240-second count average, or standard count number which provides an internal check of the probe's detector from one reading time to the next.

A range of soil moistures were used for calibration by sampling during naturally occurring wet and dry conditions. Separate calibration curves may be developed for different soil horizons to account for soil surface and air influence on shallow readings. In addition, for each monitoring site and soil depth, soil bulk density was determined using the core method. Probe readings of gravimetric water content are converted to volumetric water content by multiplying the hydroprobe-generated estimates of gravimetric water content by the value of soil bulk density. Soil water content for all 11 sites was analyzed to quantify changes over time at various soil horizons (Attachment 1 Figure 5).

Evapotranspiration (ET) on agricultural fields is influence by evaporative demands of the atmosphere, the amount of transpirational area of a crop, and the availability of water in the soil. Surface renewal is a micrometeorological method for measuring field-scale energy fluxes and was used to estimate water lost from the cover crop canopy or bare field due to ET. It is a field-based sensor system that measures how much water vapor leaves a field (as opposed to a single plant) by accounting the energy and mass budget of individual eddies of wind that interact with plant canopies. ET was calculated from the energy residual to estimate water losses due to growth of winter cover crops (Attachment 1 Equation 1).

The canopy cover development was documented on a weekly basis using the Canopeo app developed in Matlab at Oklahoma State University. Canopeo is an easy to use tool that analyzes the fractional green canopy cover from images and videos. This allowed for a large number of images to be taken in the field that can be used to determine the canopy development throughout the season.

2) How do winter cover crops affect the economic viability of operations?

The goal of this project component was to identify trade-offs associated with winter cover cropping and how these trade-offs affect the net present value (NPV) of an operation under a spectrum of hydrologic and climate change scenarios. The main hypothesis is that the benefits of cover cropping are not captured in an annual analysis but accrue over time.

A mixed-methods approach was used to assess the key social, economic, and hydrologic factors influencing winter cover crop adoption in specialty crop systems in the Central Valley. Data was collected through a literature review, hydrologic field campaign, and semi-structured interviews. The project team received Institutional Review Board exemption #Human Research Protections-312 for the interview questions, which took place from 2016-2018 (Attachment 1 Table 2). The sample of growers included six cover crop adopters, two non-adopters, and four growers who were “in-between”. The sample includes growers participating in the hydrologic field campaign, whom were asked to recommend additional growers, and the final sample reflected the diversity of operations throughout the region (i.e. climate, crop type, conventional vs. organic management, size). Majority of the interviews were transcribed, and all interviews were analyzed to distill physical descriptors, anecdotal experiences, and economic data from each grower (i.e. perceived monetary costs and benefits).

The interview results were used in the development of a partial budget cash-flow model to answer project research questions. The project team compared the costs and benefits of winter cover crops to understand how the trade-offs associated with this best management practice affect an operation’s baseline revenue (Attachment 1 Figure 9). A partial budget only captures costs and benefits that are expected to change due to a change in the operation, therefore variables are only included if they represent a change from the baseline.

The 17 variables that were applicable to production systems in California's Central Valley were monetized with both lower and upper values to capture the range of possible prices based on author discretion (Attachment 1 Table 3). Values were sourced from personal communication with growers, a literature review, and prices from UC Cost and Return studies. All costs and benefits were aggregated and reported in 2017 US dollars per acre. The greatest challenge was to assign monetary value to perceived costs and benefits based on anecdotal experiences of cover crop adoption, which can vary greatly between operations and may only have tangible impacts after several years.

This project does not enhance the competitiveness of non-specialty crops.

The project staff have a number of superb partners on this effort including several UC Cooperative Extension colleagues, a number of farmers and connections with major specialty crop industry representatives. The knowledge base from these partners benefitted the project’s success.

Goals and Outcomes Achieved

ET was measured using surface renewal lite stations and Tule sensors on several sites throughout the 2016-2018 cover crop seasons. Preliminary results from Tule show that there may not be a difference in cover crop ET based on location in the Central Valley, but excess ET due to winter cover crops compared to bare fields is double in the south the UC Davis West Side Research and Extension Center compared to the north UC Davis’ Russel Ranch Sustainable Agricultural Facility for Long Term Research in Agricultural Stability (LTRAS) (Attachment 1 Figure 6). There also appears to be a large difference between years, with a more significant difference seen in the northern part of the valley. These results are very preliminary, and the data requires significant attention going forward to ensure quality control. Preliminary results from the surface renewal station at LTRAS show that winter cover crops generally have slightly higher crop coefficients than bare fallow land (Attachment 1 Figure 7).

Tule data was compared to results from the more robust surface renewal lite station to validate the use of Tule sensors during the winter season. However, a thorough data cleaning must be completed for the data from the surface renewal before any comparisons can be made.

At each study site, the project team collected cover crop biomass samples for determinations of dry weights and N content. Please see Attachment 2 for an example of the biomass production of the Five Points, California study site. In addition, the Attachment 1 summarizes the range of study site samples that were collected and submitted to the UC Analytical Laboratory for N content determinations.

A sensitivity analysis was performed to identify which inputs were most influential on the annual baseline partial budget and ensure that those values were given sufficient attention. The value of each variable was annualized to represent an average price over the 15-year period. The analysis of the partial budget for processing tomato operations revealed the highest sensitivity to changes in yield (35 percent) and contractual noncompliance (13 percent). Fertilizer cost savings, termination, and seed contributed comparable amounts to the budget (7 to 9 percent). The almonds cover crop analysis unfortunately was not completed during the grant term.

The preliminary results show that using winter cover crops can increase baseline revenue for both annual and perennial cropping systems in the Central Valley. Processing tomato operations see this change between four and 10 years, based on the range of values (Attachment 1 Figure 11). The NPV of these partial-budgets ranged between $465 - $941 per acre for a 15-year time-horizon when a discount rate of 1.8 percent was applied. Almond operations see this profit between five and seven years (Attachment 1 Figure 12). The NPV of these partial-budgets ranged between $984 - $1,763 per acre under the same assumptions.

Information developed was designed to fill a long-standing knowledge gap related to the magnitude of cover crop water use and water-related implications under drought conditions and limited surface water supplies and will inform decision-making with science-based hydrologic and agronomic data. Activities consisted of field monitoring of soil water content, compilation and analysis of data, and farmers surveys. Please see Attachment 1 for more information.

A project target was to survey 500 San Joaquin Valley tomato and almond farmers in order to calibrate their initial knowledge and impressions about cover crop water use as a baseline for the project. Unfortunately, the project team was unable complete the amount of surveys which was an overly ambitious goal. This was due to the fact that all event locations did not have the capabilities for computers or phones to conduct the surveys.

The project team instead focused on individual farmer surveys to gather and analyze deeper information related to cover crop use by the target audience. This methodology was used to generate a better understanding of the details the project team sought to compile. These surveys were lengthier and more detailed to achieve a baseline for farmers. A total of six cover crop adopters, two non-adopters, and four growers who were “in-between” were surveyed.

Another project goal was to reach 900 individual farmers with knowledge generated by the project’s completion. The project team reached a total of 1,028 people through a variety of educational activities that were conducted (Attachment 2). There were more than the 200 targeted that participated in the project team’s major field educational training event in June 2016 alone.

This project was designed to conduct farm studies and determine the biomass production potential of various winter windows for single and diverse multi-species cover crop mixes, changes in soil water storage under these cover crops compared to fallow, and data on the C and N capture and provision potential of these mixes to inform farmers of the true tradeoffs associated with this practice. The long-term goal of the project was to achieve a 20 percent increase in the adoption of this management practice. Since there was no historical data related to the use of cover crops in California, the increase in cover crop adaptation was difficult to accurately quantify by the end of the project term. The project team estimates that this practice is currently used on less than 5 percent of annual crop acreage, with a similar percentage in almond orchards. The project team is confident that with continued research and outreach, the 20 percent increase in cover crop adoption will be reached.

The project team has made substantial and significant progress toward a data-based cost-benefit analysis of cover crops in San Joaquin Valley tomato and almond production systems. The database will include an additional sampling season. Results from each sampling season will be consolidated in the 2019 updated database. The project team efforts and results have and will continue to research the tradeoffs associated with actual cover crop use with respect to water use of the cover crops versus conventional winter fallow and will disseminate research results when all data and analysis are complete.

Beneficiaries

Beneficiaries of this information are the tomato farmers and almond orchardists who represent over 280,000 and 780,000 acres of California cropland, respectively. It is expected that the findings of this study will also have value throughout much of the irrigated western United States where similar, high-value specialty crops are also produced. Findings will continue to be presented to California Almond Board, California Tomato Research Institute, and California Tomato Grower Association meetings as well as shared with local chapters of the California Federation of Farm Bureaus Young and New Farmer and other new farmer associations as possible and will be disseminated widely via video updates posted on the Conservation Agriculture Systems Innovation website with links to specialty crop commodity board. Project results will be distributed at the World Agricultural Expo in Tulare, California. The project team will also post several project related videos in 2019.

By the conclusion of the project it was estimated that 50 people received project results thus far, however, higher numbers are envisioned by the end of 2019. These outcomes will have specific economic value and the process of modelling that value will be completed beyond the project term.

Lessons Learned

The project set out to characterize and determine tradeoffs associated with the practice of cover crops. The continued results of the project research will be critical for both producers and regulators as they strive to meet the challenge of improving water management and maintaining agricultural production under a changing hydrologic and political landscape. Due to the amount of data yet to be generated, project overall results were not completed during the grant term. The project team will continue to reach project goals in the next season and anticipate publishable findings and results will be completed in 2019. A lessoned learned would be strive for project goals that are attainable within the grant term.

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

Additional Information

Please see Attachment 1 and Attachment 2

A website has been created to compile project information and will be updated as needed:
https://covercrops.ucdavis.edu/

Conservation Agriculture Systems Innovation blog:
http://casi.ucanr.edu/?blogpost=24339 &blogasset=14128

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 38	**Project Title:** Improving Water and Nitrogen Use Efficiency of Cool Season Vegetables: Brussels Sprouts, Celery, High Density and Organic Crops	
Grant Recipient: The Regents of the University of California, Agriculture and Natural Resources	**Grant Agreement No.:** SCB15038	**Date Submitted:** December 2018
Recipient Contact: Richard Smith	**Telephone:** (831) 759-7357	**Email:** rifsmith@ucdavis.edu

Project Summary

California is the main producer of Brussels sprouts, celery and organic salad mix products in the United States. The vegetable production district of the Central Coast is an important production area that produces 90 percent of cool season vegetables in the summer. Worth approximately $292 million, these crops are an important component of the production mix of cool season vegetables. High inputs of water and nitrogen fertilizer are required to achieve economical yields and acceptable market quality. Leaching of nitrate from vegetable crop production has contaminated ground water supplies in these regions, and growing operations are now under increasing regulation and scrutiny by the Central Coast Regional Water Quality Control Board. To meet water quality objectives, growers need to improve both irrigation and nitrogen management of their crops.

This project developed basic agronomic information on Brussels sprouts, celery and organic baby lettuce that allowed their inclusion in the online tool, CropManage (https://v3.cropmanage.ucanr.edu/Home/SplashPage?ReturnUrl=%2F). CropManage utilizes weather, soil, and crop data to provide in field decision support to growers in using water and nitrogen fertilizer efficiently for producing a growing list of crops (e.g. lettuce, spinach, broccoli, cauliflower, processing tomatoes and almonds). This tool helps growers make efficient nitrogen and water application decisions. Minimal guidance was available to coastal growers with respect to the management of nitrogen in organic vegetable production. This project provided agronomic data on these crops that filled in key gaps in the available knowledge of how they grow. Each of the crops covered by this project exemplified specific characteristics: Brussels sprouts – a deep rooted long-season vegetable with high nitrogen requirement; organic baby lettuce – a short life cycle (e.g. 30 days), with shallow root system and dependent on slow releasing organic fertilizers; and celery with a moderate to high demand for nitrogen and high water use to achieve acceptable yield and quality. This project addressed the goal of environmental stewardship and conservation by assisting vegetable farmers in reducing inputs of nitrogen fertilizer and water, thereby conserving and improving the quality and safety of ground water supplies.

This project adds to and built upon the work developed by the 2013 Specialty Crop Block Grant Program (SCBGP) Project 43: *Online Irrigation and Nitrogen Management Tool for Cool Season Vegetables* which developed basic algorithms on crop coefficients, nitrogen uptake and rooting depth for broccoli, cauliflower, cabbage and spinach. This basic agronomic information allowed for inclusion of these crops in the CropManage database. The number of crops covered by CropManage is now expanding to make it a more effective tool for many growers. The current project expands upon the previously funded SCBGP project by adding Brussels sprouts, organic baby lettuce, and celery into the program.

Project Approach

The following tasks were completed to meet the project objectives:

Task 1 – Three commercial fields of celery, Brussels sprout and baby lettuce were evaluated in both 2016 and 2017. Multispectral digital camera evaluations were conducted to collect Normalized Difference Vegetation Index (NDVI) data and evaluate canopy cover development on a weekly basis. Crop biomass was evaluated three to six times during the crop cycle and crop nitrogen uptake was measured and rooting depth was evaluated (Figure 1). The data was analyzed and used to develop algorithms that estimated crop coefficient, root development, and nitrogen uptake. Given the deep rooting nature of Brussels sprouts, soil nitrate was evaluated deeper in the soil profile. Parameters from these measurements were incorporated into CropManage algorithms.

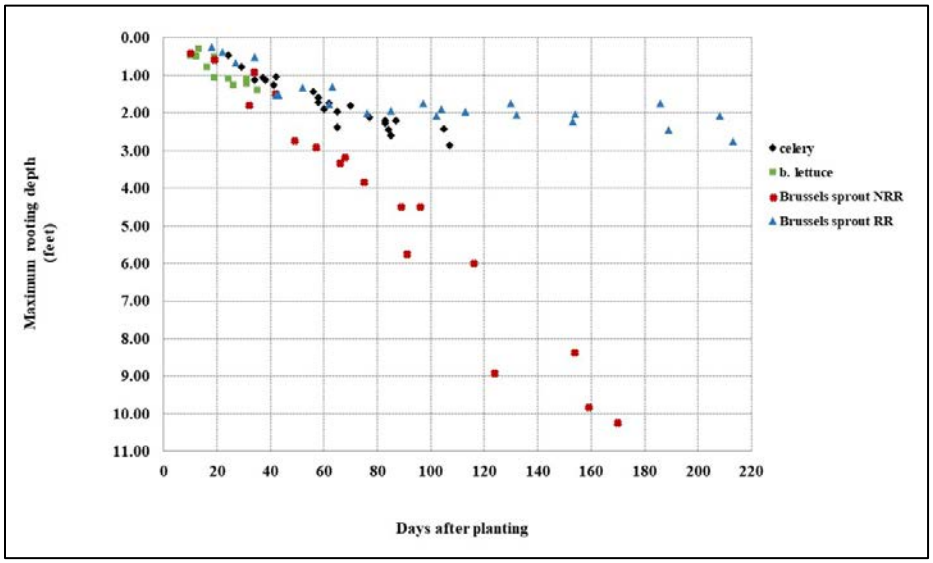


Figure 1. Rooting depth of baby lettuce, Brussels sprouts (NRR – no rooting restriction and RR – rooting restriction) and celery over the crop cycle

Task 2 – Evaluations of mineralization of nitrate from soil organic matter were conducted on 20 pairs of conventional and organically managed fields. Paired fields were located on the same soil types and had similar cropping patterns. Evaluations of nitrogen mineralization consisted of laboratory evaluations of nitrogen and carbon mineralization, water extractable carbon and nitrogen potassium permanganate incubations, as well as soil organic matter and total nitrogen content. Correlations of these tests were run to determine their predictive power (Table 1). Results of these evaluations were used to refine algorithms used in CropManage to predict nitrogen release for soils in both organic and conventional production.

Table 1. Significant correlations between soil parameters and mineralization of N from in-field and laboratory evaluations.

Paired variables		Pearson Correlation Coefficient	P-value
Initial mineral N	Final N mineralized	0.78422	<.0001
Final N mineralized	Initial mineral N	0.78837	<.0001
	N mineralized ppm	0.87773	<.0001

Paired variables		Pearson Correlation Coefficient	P-value
N mineralized ppm	N mineralized lbs/acre/day	0.98764	<.0001
Total soil N	Total soil carbon	0.87252	<.0001
	Total phosphorus	0.82756	<.0001
	Soil organic matter	0.85622	<.0001
	% Sand	-0.81258	<.0001
	% Clay	0.85007	<.0001
Total soil carbon	Total phosphorus	0.84862	<.0001
	Potassium	0.87897	<.0001
	Soil organic matter	0.99116	<.0001
	% Sand	-0.81706	<.0001
	% Clay	0.91713	<.0001
Total phosphorus	Potassium	0.74148	0.0002
	Soil organic matter	0.84986	<.0001
	% Sand	-0.82064	<.0001
	% Clay	0.87689	<.0001
Potassium	Soil organic matter	0.88707	<.0001
	% Sand	-0.77324	<.0001
	% Clay	0.87627	<.0001
Soil organic matter	% Sand	-0.8895	<.0001
	% Clay	0.95781	<.0001
	Water extractable organic carbon	0.73726	<.0001
Water extractable organic carbon	Water extractable organic N	0.80615	<.0001

Task 3 – The data collected in Task 1 were analyzed and used to develop algorithms used to model growth of the crops included in this project. The algorithms were included in CropManage.

Task 4 – Large scale field evaluations were conducted to confirm the accuracy of the predictions made by CropManage. These evaluations were conducted for celery and lettuce. Brussels sprouts presented difficulties for conducting this type of evaluation. The deep-rooted nature of the crop and its susceptibility to rooting depth impairments necessitated further future evaluations on this crop to confirm the accuracy of the algorithms developed by this project. Figure 1 shows rooting depth data for Brussels sprouts in fields with no impairments to rooting depth (roots reached to ten feet deep by the end of the cropping cycle) and Brussels sprouts in fields with an impairment to rooting depth (e.g. a dense clay pan that reduced rooting depth to approximately three feet). Brussels sprouts grown on deep soil with no rooting impairment required less nitrogen fertilizer and scavenged a great portion of the nitrogen taken up by the crop, whereas Brussels sprouts grown on shallow soil required greater amounts of nitrogen fertilization to achieve good yields.

Task 5 – Surveys were conducted through a focus group held in December 2017 and during six hands-on training workshops held in 2017 and 2018. In addition, growers who were major users of CropManage were interviewed.

Tasks 6 – An evaluation was conducted to determine if the use of CropManage online tool had increased and if growers had improved nitrogen and water use efficiency. Data on the number of users and fields managed using the CropManage was collected in the survey. Additionally, the number of recommendations per month that the CropManage software provided to users was summarized. Results showed that the number of fields managed with CropManage increased by 85 percent between 2015 and 2017. Additionally, the number of fertilizer and irrigation recommendations provided by CropManage increased by 73 percent and 47 percent, respectively, during the same time interval.

Task 7 – CropManage users were surveyed to determine the usefulness of the decision support tool and to identify areas to improve the online application.

All grant funds were tracked to ensure that grant funds solely benefitted the competitiveness of specialty crops.

University of California, Davis partners were responsible for conducting laboratory evaluations of mineralization of nitrate from soil organic matter.

Goals and Outcomes Achieved

The primary performance goal for this project was to expand the number and types of crops included in CropManage. Selected crops in this project included a diverse set of cool season vegetable crop (Brussels sprouts, celery and organic baby lettuce). Each crop, in its own way, presented a challenge to growers to improve water and nitrogen fertilizer management.

Activities completed: Two years of evaluations were conducted with cooperating growers on commercial production fields of water use, crop development, rooting depth and nitrogen uptake by Brussels sprouts, celery and organic baby lettuce. Evaluations provided data to develop algorithms for use by CropManage software to provide recommendations for making fertilizer and irrigation decisions. Evaluations on nitrogen mineralization were completed on 20 paired organic and conventional production fields to provide data on nitrogen mineralization from soil organic matter. These data allowed for refinements to the algorithms used by CropManage to estimate the quantity of nitrogen released from soil organic matter over the course of the crop cycle.

CropManage users were surveyed to determine the usefulness of the decision support tool and to identify areas to improve the online application. urveys were conducted through a focus group held during December 2017 and during six hands-on training workshops held in 2017 and 2018. In addition, growers who were major users of CropManage were interviewed.

The adoption of CropManage by Brussels sprout, celery, and organic baby vegetable growers on the central coast was a long-term goal of this project.

Field evaluations conducted during the project developed data that documented nitrogen uptake by Brussels sprouts, celery, and baby lettuce. This data will help guide growers to more efficient use of nitrogen in crop production. This data also showed some of the subtleties in Brussel sprout fertilizer programs. Soil conditions greatly affected the need for nitrogen fertilizer and the plant's ability to scavenge nitrogen from the soil: deeper soil with no impeding layers allowed the crop to grow roots to over eight feet deep and utilize the nitrogen encountered there to substitute for fertilizer nitrogen; however, soils with impeding layers (clay pans, abrupt soil texture changes) reduced rooting depth and dramatically reduced nitrogen scavenging. Based on an evaluation of use of CropManage by growers, it was estimated that 10 percent of cool season vegetable growers currently used this on-line tool to guide their fertilizer and irrigation decisions. This result, indicated that the short-term goal of the project was met. CropManage is currently unable to querie by commodity, therefore the team was unable to determine whether 10 percent of the acres of celery, Brussels sprouts, and organic vegetables in the Salinas Valley had begun to use CropManage. To remedy this, the project team began working with programmers to build this capacity into the program. It is estimated that this information will begin to be available by early 2019.

CropManage provided less than 900 fertilizer and water recommendations per month during peak production season before the start of this project. Use of CropManage steadily increased during the life of the project, providing as much as 1,500 recommendations per month during the same period in 2018.

The CropManage online decision support tool for fertilizer and water management was expanded to include Brussels sprout, celery, and baby lettuce. Field surveys conducted during this project provided the data needed to develop the algorithms to include Brussels sprouts, celery, and organic baby lettuce into CropManage. CropManage had 1,600 registered users by the end of the project duration. Total CropManage registered users increased by approximately 30 percent during the life of the project.

Beneficiaries

The beneficiaries of this project were producers of the cools season vegetables, Brussels sprouts, celery, and organic baby lettuce as well as the shippers of these products, and municipal water suppliers on the central coast of California.

This project directly benefited the 1,636 registered CropManage users by increasing the number of vegetable commodities supported by this online decision support tool.

Lessons Learned

The user interface for the CropManage software needed to continually be updated to match improvements in technology. Computer programming costs greatly increased during the project which required a revaluation of the project budget. The increase in costs was due to more time being needed to expand the online tool to accommodate the new commodities and features than was initially estimated. Grower adoption of online applications such as CropManage could be improved by providing an intermediate application that would streamline the user interface so that navigation within the application and data entry was simplified for field workers and farm managers.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 39	**Project Title:** High Elevation Vineyard Irrigation Model Beta Test	
Grant Recipient: Calaveras Winegrape Alliance	**Grant Agreement No.:** SCB15039	**Date Submitted:** December 2017
Recipient Contact: Carolyn Nelson	**Telephone:** (209) 728- 9467	**Email:** cwagrant2@gmail.com

Project Summary

The purpose of this project was to beta test the computerized high elevation (HE) irrigation model (the Model) developed over the 2012, 2013 and 2014 growing seasons while also verifying a reduction in water usage, without compromising fruit quality or tonnage. HE vineyard experts highly recommended beta testing before the Model and Best Management Practice (BMP) guidelines were released to the general public. Beta testing provided the opportunity to analyze and incorporate selected grower participant (GP) feedback/data and identify and correct potential challenges. The goal was to ensure the Model and protocol would function properly in a real-world setting. This was a necessary preemptive phase before public release to minimize risk in compromising plant health, grape quality and crop production and also identify issues that did not come up during the alpha phase.

Agriculture accounts for 70% of water use in California. As politicians and water experts work on long-term water efficiency regulations for California, it is important to develop practical and beneficial water saving tools for growing HE California wine grapes. It is estimated there are more than 20,000 acres of California vineyards at over 1,000 foot elevation in regions including Lake, Mendocino, Calaveras, Amador, Tuolumne, El Dorado, Napa, Monterey & San Luis Obispo counties. Water saving practices are especially important for growers in HE regions because of the arid climate experienced during the growing season versus that which exists in valley or coastal regions. Using standard irrigation practices in HE vineyards, plant water loss during high temperature episodes can be more than 30% with fruit yield reductions estimated to reach 50%. Efficient water use in HE vineyards could potentially increase a county's tax revenues, as meeting vines optimal moisture needs will improve vine health, grape composition and phenolic attributes; thus enhancing the competitiveness of HE grapes. Strong healthy vines require less invasive vineyard practices which reduces the need to enter a vineyard to apply pesticides, fumigants and chemicals; decreasing dust abatement and soil compaction.

This project built upon the 2011 Specialty Crop Block Grant Program Project 27: *Improving Water Use Efficiency in High Elevation (HE) Vineyards*. The project created a draft water efficient irrigation model that was tested in two vineyards. This project also built upon the 2012 Specialty Crop Block Grant Program Project 42: *Improving Water Use Efficiency in High Elevation Vineyards, Phase II & III*. The project created a computerized model of the draft irrigation model and was tested in four HE vineyard sites, each with different wine grape varietals, rootstocks, and historic irrigation practices. These alpha tests showed that HE vineyards irrigated using schedules based on 10-day high temperature forecasts typically used approximately 20% less water than HE vineyards using a traditional irrigation schedule. The wine and grape quality was also improved. Tests showed higher Yeast Assimilable Nitrogen (YAN) and lower acetic acid bacteria values in vineyards irrigated using the Model. The success and progress achieved during these two prior projects led to the current project - a beta test designed to prepare the Model for release to the public.

Project Approach

Preparation:

The project staff met to determine possible vineyard sites and schedule a monthly staff meeting. The staff then contacted vineyard owners in four HE counties and visited four potential vineyard sites. Two growers were selected based on vineyard criteria and willingness to follow the irrigation Model and submit a section of their vineyard for research. The selection of the participants was then shared with the Calaveras Winegrape Alliance (CWA) membership. The two vineyards selected for the study were in West Point, California and San Andreas, California. The West Point vineyard is at a 2,800 foot elevation and the grape varietal is Syrah. The San Andreas vineyard is at a 1,200 foot elevation and the grape varietal is Zinfandel. The GPs provided historical irrigation data so a baseline could be established. Both participating vineyards were revisited by the Project Manager (PM) to further study the irrigation layout and the modifications necessary to isolate a test and control block in each vineyard. The PM flagged a test block in each vineyard, which included five rows of 10 vines (50 total vines) that would be irrigated using the Model. The GPs were instructed to irrigate the remainder of the vineyard as they have historically. Fifty adjacent vines were marked and labeled as the control block. Three CWA Assistants (CAs) were hired to assist with office and field work. Soil pits were dug in the West Point vineyard on April 2, 2016 and in the San Andreas vineyard on April 7, 2016. The Industry Consultant (IC) sent soil samples to A&L Labs and the results were received May 3, 2016. Soil profile information was used to properly install soil moisture sensors as well as to calculate the water holding capacity of the soil. The San Andreas vineyard had an estimated 6.4 inches total of available water to 62 inches (10% water holding capacity). In West Point, there was an estimated 6.8 inches total available water to 52 inches (13% water holding capacity). The PM modified the irrigation systems on April 11, 2016 so the GPs could irrigate the test and control block separately. All supplies necessary for testing (porometer, plant moisture stress (PMS) instrument, soil moisture sensors and a tape measure) was procured before testing began on April 18, 2016. Additionally, soil moisture probes were installed in April in the test and control block in each vineyard at a 16-inch and 36-inch depth.

Ongoing activities and outreach:

Monthly project staff meetings were held and the CAs gave updates on data collection progress and grower feedback. The IC and the Technical Manager (TM), were often present to help interpret data and advise the team. A CA also gave a grant update at the monthly CWA Board of Directors and Educational Meetings. The County Agricultural Commissioner and University of California Cooperative Extension (UCCE) Farm Advisor were generally present at the meetings and were available to disseminate the information when requested. GP feedback was collected periodically in order to inform the grant staff of adjustments to the Model regarding user-friendliness and consistent directions. The PM and PDs kept careful track of the project timeline and gave reminders and instructions at the monthly meetings, by email, and/or phone. The PM and CAs instructed the GPs on irrigation Model protocol in person. Instructions were given and questions answered during follow up visits, emails and phone calls. The CAs also monitored the GPs in person on a biweekly basis. The PM sent emails to the GPs bimonthly to remind them to carefully document all irrigation dates and duration using the designated spreadsheet. The CAs collected and documented plant health and cane growth data biweekly starting on April 18, 2016 until harvest. A CA checked the online directive on a daily basis and documented the directive and forecast.

Data collection and analysis:

Petiole samples were taken on June 13th (during bloom) and sent to A&L Laboratories. The results showed a 0.37% lower potassium level in the control block of the San Andreas vineyard. As a follow up, leaf samples

were taken from both vineyards a week before harvest. The results showed no significant change or deviation within Cation Exchange Capacity (CEC) values. The CEC is the ability of the soil to hold essential nutrients. Weather monitoring sensors were installed at the West Point vineyard on June 13, 2016 and had already been installed in the San Andreas vineyard. Staff documented any confusion or suggestions from the GPs regarding the use of the website and Model.

The CAs organized and executed a rigorous pre-harvest testing put together by the PM, IC and TM. Brix measurements were taken biweekly starting in the beginning of August. Shortly before harvest, juice and whole grape samples were taken and sent to ETS Laboratory for a Basic Juice Panel, Grape Phenolics Panel and Grape Water Content analysis. Sixty pounds of grapes from each block were also harvested and delivered to the TM to be made into wine. At the end of fermentation the samples of wine from each block were shipped to ETS Laboratory for a Rapid Phenolics Panel. The results were received back from ETS Laboratory and were analyzed by the contracted wine analyst and IC. In general, data showed that treatment effects were negligible or conflicting. The Rapid Phenolics Panel showed slightly higher tannin levels in the test block of the West Point vineyard - 163 mg/L higher than in the control block. The results suggest that the different irrigation practices used in the test and control block did not significantly modify grape composition.

Follow up, evaluation and final BMP:
At the end of the season, staff met with the GPs to discuss their experience with the Model and to document any challenges or confusion they faced. Both GPs indicated that they would use the Model again if a few changes were made to the website. First, they requested that the program have memory to eliminate the need for growers to 1) Track that irrigations occur no more than once every six days and 2) Track that irrigations occur at least once every 16 days. This was the primary mistake made by GPs while using the Model during this trial. Second, The GPs also requested that the website include a feature enabling them to review their irrigation history for the season. Third, the GPs suggested that the website give only one irrigation directive per day instead of changing throughout the day as the forecast changed. This would eliminate confusion that occurred when the GP checked the directive more than one time per day. Fourth, the GPs required clarification of what to do when the Model indicated “Irrigate Tomorrow” and the following day’s directive did not state “Irrigate Today.” The BMP was adjusted to address the GPs recommendations and concerns.

Website adjustments:
In April 2016, the online irrigation Model and website was evaluated and the following changes were made to the texts and directions:
1.) Directives were shifted so they appear directly under the zip code so growers can see it easily at the top.
2.) Directions that were generated were changed so that only one directive appeared below the zip code.

Following the final meeting with the GPs and evaluation of the program, the contracted computer programmer was contacted to make the following necessary website modifications that came to light during the beta test:
1.) A new website was created with memory that allows for individual accounts for each grower. Growers will no longer need to manually track days between irrigations. A list of all past irrigation days from the current season will also be listed.
2.) A change was made so the directive given the first time the grower checks the Model each day will be the directive shown for the whole day, eliminating the directive changing throughout the day.
3.) The only directives given will be “Irrigate Today” or “Do not irrigate at this time.”

These changes will significantly decrease the chance of human error and were incorporated into the BMP. To access the new site go to http://irrigationtool.calaveraswines.org.

Dissemination:
PowerPoint presentations were provided at the CWA Educational Meeting on February 3, at the CWA Board of Directors meeting on February 16, at the Calaveras County Farm Bureau Board of Directors meeting on March 14 and at the Calaveras Grown Board of Directors meeting on March 15. A total of 85 were in attendance. Informational pamphlets were available at every meeting and the presentation remains available on the CWA website (the presentation and pamphlet are attached). Brochures were also distributed to the Departments of Agriculture in Tuolumne, Calaveras and Amador Counties, neighboring winegrape grower and vintner associations and the Calaveras County Master Gardener training class. A press release was written and sent to the local papers and other interested parties.

The project did not benefit commodities other than HE wine grapes, a California specialty crop.

Significant contributions and role of project partners include:
- The CWA provided office space and website assistance. They will continue to provide support in the form of ongoing website maintenance.
- The Calaveras County Agricultural Commissioner's office provided necessary contact information for growers.
- The Agricultural Commissioner and UCCE Farm Advisor attended educational meetings and received updates on the project in order to disseminate the information in the HE counties in which they work.
- Calaveras Grown and the Farm Bureau allowed the grant staff to present grant updates and a final presentation to their membership during monthly meetings.
- Retired Calaveras County Agricultural Commissioner, contributed a practical approach to grower outreach and acted as a communication liaison with the CWA Board of Directors.
- Technical Manager and Model developer, gave crucial advice and background. He also created statistical graphs to represent soil moisture, irrigation, porometer, PMS and cane length data.
- Vineyard Manager, executed soil sampling and gave ongoing advice and support to the grant staff. He also aided with analysis of the petiole and leaf samples as well as the soil moisture, irrigation, porometer, cane length and PMS data.
- Viticulture and Plant Science Advisor, UCCE Mendocino County, recommended this beta testing phase of the project.
- The GPs were local vineyard owners, CWA members and active members of the community. Their diligence, cooperation and thoughtful feedback was critical to the success of this project.
- Contracted wine analyst, analyzed all juice, wine and whole grape test results and gave a detailed report.
- Vineyard owner and biologist, gave support and a scientific approach to the development of the Model.

Goals and Outcomes Achieved

Following the identification of the vineyard sites in San Andreas and West Point, historical vineyard irrigation data was collected from the GPs in order to calculate a "normal amount" that must be established in order to use the Model. In April, the IC dug soil pits and conducted testing in order to calculate the soil water holding capacity and identify the soil horizons. This data was used to properly install the soil moisture sensors. Previously installed weather monitoring sensors recorded daily temperatures, reference evapotranspiration, solar radiation, wind speed, wind direction, rainfall and relative humidity. The GPs documented all irrigation

dates and durations on a spreadsheet and were responsible for using the Model properly with minimal intervention from the grant staff. At the end of each month the GPs sent their most recent irrigation data to the PM. This data, along with online directives and feedback, was reviewed at monthly staff meetings. From April 18th until harvest, the CAs visited the vineyards biweekly and conducted comprehensive testing. The data was used to compare the test and control block in each vineyard to prove that use of the Model does not compromise vine health and/or vigor. CAs measured PMS and stomatal conductance levels as well as cane growth and soil moisture. Furthermore, biweekly photographs were taken of test vines to monitor plant growth and health. Feedback from the GPs was documented biweekly and a survey was sent out in July to all 43 CWA growers to indicate their potential adoption of the Model. Only one grower stated he/she was not interested in using the Model. Information about the Model was also disseminated at CWA Educational Meetings.

Following harvest, water usage data was compiled and analyzed carefully by staff. It was revealed that 138 gallons per vine more water was used in the test versus the control block in the San Andreas vineyard. Part of the cause was discovered to be that the GP unintentionally followed the Model incorrectly in some cases. Even so, if he had followed the Model directives perfectly he still would have used 10% more water in the test block than the control. This result could indicate that this Model is not effective in vineyards where the normal irrigation amount is so high. Standard irrigation in an HE vineyard usually ranges between four and six gallons per vine per week. This vineyard used a normal amount of 18 gallons per vine per week. The TM looked at many other possible reasons for this anomaly, including elevation and weather data, and was not able to determine the cause.

Water usage in the West Point vineyard test block was also greater (32.5 gallons per vine, more) and the cause was discovered to be an error in calculating the baseline data. Due to a computing error, the “normal amount” used to calculate the duration of irrigation was three times what it should have been. If the GP had followed the irrigation directives perfectly and the “normal amount” had been calculated correctly, 32% less water would have been used in the test block, further proving the effectiveness of the Model. PMS, stomatal conductance levels, cane growth, crop yield, and photographs were analyzed and showed no significant differences between the test and control blocks in each vineyard. The IC noted slightly higher tannin levels and a ¾ ton per acre increase in yield in the control block of the West Point vineyard which received less water than the test block. Wine phenolics, anthocyanins, brix and thermal analysis of grape juice and whole grape samples showed negligible or conflicting differences between the test and control blocks.

The long-term outcomes of this project were expected to be an increase in growers' irrigation knowledge and a reduction in growers' water usage, which would encourage widespread adoption of this new irrigation model. Through outreach and education during this grant period, many growers gained knowledge about efficient irrigation practices. This work also demonstrated that plant growth can be improved by applying irrigation at the proper time relative to forecasted temperatures. Public outreach also created an awareness and anticipation of the Model. Eighty-five were in attendance at the final presentations. A list of possible interested growers has been established and the new website will monitor who is using the Model. Some growers who used the Model during past grant periods have continued to do so and have reported continued water savings of up to 38% and some even reported improved quality.

The goal of a 20% water savings was not accomplished in either vineyard but would have been accomplished in West Point without human error (32% savings). In San Andreas the goal was not achieved as 10% more (10

gallons) water would have been used even without human error. An improved BMP and public outreach was accomplished during this reporting period.

The expected measurable outcomes of this project were to beta test the Model to substantiate a reduction in water, to improve the Model, to survey growers to indicate interest in participation and provide online availability of the Model.

The beta test was initiated at the start of the growing season and concluded at harvest. Water usage would have been reduced in only one of the vineyards if there was no human error.

The Model was confusing to use for the GPs. The GPs had to manually track days between irrigations and multiple directives were provided. The Model has been improved to eliminate the confusions.

The results of the survey indicated that only one grower was not interested in using the Model. The Model was released to the public through the CWA website and will continue to be monitored by CWA employees.

Major successful outcomes include:
Without human error, there would have been a 32% water savings in the West Point vineyard. Eighty-five HE growers and other interested parties attended presentations and are now familiar with the Model and better irrigation practices. All but one of the 43 CWA growers surveyed indicated they would be interested in adopting the irrigation Model. Both GPs from this year and two past GPs still use the Model and indicated they would be interested in participating again. So far, 375 brochures have been distributed to CWA members, the Departments of Agriculture in Tuolumne, Calaveras and Amador Counties, neighboring winegrape grower and vintner associations, etc.

Beneficiaries

All HE winegrape growers in California could benefit from the completion of this project by saving up to 20% of their normal water use. As a result, the county and state could also benefit by achieving increased tax revenue and greater water savings.

To date, five of the 43 growers in Calaveras County have committed to using the model. Per the 2016 Calaveras Crop Report, there are 700 acres of winegrapes. Not all acres are considered high elevation, making it difficult to determine potential for monetary savings. It is estimated there are more than 20,000 acres of California vineyards at over 1,000 foot elevation in regions including Lake, Mendocino, Calaveras, Amador, Tuolumne, El Dorado, Napa, Monterey & San Luis Obispo counties. By using this model, a HE grower can potentially realize savings of $138/acre with a state-wide impact that could reach $2.7 million.

This project will improve the economic viability of wine grapes by decreasing water cost, thus decreasing the startup costs for beginning growers. By reducing the cost burden on current growers, money saved could be used to improve and/or expand wine grape production. Increased vineyard productivity could potentially increase a county's tax revenues, as meeting vines optimal moisture needs will improve vine health, grape composition and phenolic attributes; thus enhancing the competitiveness of HE wine grapes.

Lessons Learned

During the final months of this project, the project staff was reminded that the lessons learned and challenges overcome during a beta test is more important than the ultimate outcome. They were also reminded that any worthwhile endeavor takes time and refinement. Negative results taught the staff that directions need to be so simple and clear, that there is very little chance of human error. They also learned the importance of checking any calculations or important baseline data. Positive experiences taught them that people are willing to try and learn something new. They were also pleased to learn that the foothill communities are eager to conserve water and are willing to put forth effort to accomplish water savings.

The only unexpected outcome was the failure of the Model to reduce water usage in the San Andreas vineyard.

Lessons learned to help others expedite problem-solving:

- Check, double check and triple check any important calculations or baseline data.
- Make sure the tool is user-friendly and simple to follow.
- Monitor the project closely so mistakes can be detected and corrected immediately.
- Make plans and budget for further testing if the project outcomes are unexpected.

Additional Information

Please see attachments:

1. Best Management Practices Document
2. Powerpoint Presentation
3. Brochure
4. ETS Laboratories Results Summary
5. Statistical Graphs
6. Microphotos

USDA Project No.:	Project Title: Updating Crop Water Use and Crop Coefficients of Mature Pistachio Orchards in the San Joaquin Valley.	
40		
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB15040	**Date Submitted:** December 2018
Recipient Contact: Daniele Zaccaria	**Telephone:** (530) 219-7502	**Email:** dzaccaria@ucdavis.edu

Project Summary

In the last 10-15 years, the pistachio acreage in California has more than doubled, and expansion mainly occurred in the southwestern part of the San Joaquin Valley on farmlands previously planted to annual crops and cotton, and in areas with naturally high soil salinity. However, little information is available to growers on actual evapotranspiration (ET) and crop coefficients (Kc) of mature pistachio orchards grown with micro-irrigation on non-salt affected soils and on saline soils, where the canopy development, orchard water use, and production may be adversely affected by the soil-water salinity (low soil osmotic potential and physiological tree response). Pistachio growers need updated and reliable information on orchards' water use to optimize irrigation and nutrient use efficiency, and achieve full economic gains from their orchards, while maintaining sustainable soil and water quality.

During this project, the research team conducted site-specific field measurements of actual ET and Kc in mature commercial pistachio orchards grown on non-salt-affected and saline soils with micro-irrigation, investigating the impacts of increasing soil-water salinity on canopy growth and crop ET.

The importance of this project consists in the provision of updated information and methods that can be readily adopted by growers to enhance the water productivity of pistachio production in the face of increasingly limited, costly, and variable quantity and quality of water supplies. The project integrated research and extension activities to address a critical challenge facing California pistachio growers to irrigate more precisely through accurate irrigation scheduling, while maintaining sustainable soil and water quality in the orchards.

This project was relevant and timely for the pistachio production community under the prospects of increasing scarcity and variability of water supply, both in terms of quantity and quality, in relation to the combined impacts of recurring droughts, curtailments of surface water allocations, aquifer over-drafting and natural or induced soil salinity.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The project team instrumented four mature well-managed pistachio orchards grown on non-saline and increasingly saline soils in the San Joaquin Valley and measured various micro-meteorological and crop parameters over two consecutive crop seasons, i.e. 2016, 2017 and part of the 2018 crop season. In details, the team measured the actual tree ET using the residual of the energy balance (REB) method with a combination of Eddy Covariance (EC) and Surface Renewal (SR) equipment, measured and mapped the soil electrical-conductivity (EC) with the electromagnetic (EM) survey technology, measured the midday canopy light

interception in the Photosynthetic Active Radiation (fPAR) region of light using a Mule Light-bar mobile equipment, measured the midday stem water potential (Ψ_{SWP}) with pressure chambers, and acquired high-resolution remote sensing images in the visible and near-infrared (VNIR), and thermal infrared (TIR) light regions of the spectrum through multiple airborne overpasses.

Based on the collected field datasets, the team determined that mature pistachio orchards grown on non-saline soils have maximum light interception of about 70 percent, seasonal cumulative ET of 36-40 inches, and maximum crop coefficient around 0.92. The research team also found that the actual crop coefficient values of mature non-salt affected orchards are about 20 to 30 percent lower than those commonly used by pistachio growers in the San Joaquin Valley to schedule irrigation. These commonly used Kc values were determined in previous studies conducted by the University of California (UC) academics in late 1990's and early 2000 for sprinkler-irrigated pistachio orchards.

It was also determined that soil-water salinity reduced canopy cover and increased tree water stress. Trees grown in salt affected sites had light interception ranging from a maximum of 65 percent to a minimum of 25 percent, depending on the salinity level, ET about 10 to 30 percent lower than the non-saline orchards, and Ψ_{SWP} values about 10 to15 bars lower than the non-saline orchards.

The team determined the functional relations between light fPAR, ET and Kc along the different growth stages of the crop seasons. The relations between soil-water salinity, fPAR, ET and Kc was also investigated, but during the course of this project the team realized that the soil-plant-water relations in salt affected soils are more complicated than originally anticipated. As a matter of fact, besides the soil-water salinity (ECe), there are multiple other soil-related factors affecting the tree canopy development and the resulting ET and Kc, including the soil structure, sodium absorption ratio (SAR), saturated percentage (SP), soil pH., concentration and diffusion of oxygen, as well as hypoxia and asphyxia. These aspects require additional and more in-depth investigations that extend from soil physical and chemical properties to root and tree physiology.

The project did not benefit commodities other than pistachio.

The project Principal Investigator (PI) coordinated and oversaw all activities conducted over the course of the project and contributed in the collection of field data and remote sensing information, as well as in the processing, analysis, interpretation and outreach of the project results.
Co-PIs contributed their scientific expertise to the design of experiment, instrumentation of the study orchards, installation of all the field supplies for systematic data collection, acquisition of remote sensing imagery, as well as to data analysis and interpretation, and outreach of project outcomes.
The Bio-meteorologist guided the project team in designing the experiment, purchasing, installation and maintenance of field instrumentation, and helped with data collection, processing and interpretation.
Co-investigators led the specific tasks of surveying the study orchards for collection of light interception measurements in different stages of the crop growth, and for nut yield sampling and analysis. The two Co-investigators also coordinated activities with the rest of the project team and contributed to analysis, interpretation and outreach of field datasets to various stakeholders within the pistachio production community.

Project Scientist supervised most of the logistic organization for field data collection and surveys and coordinated the remote sensing data acquisition with the suppliers of high-resolution airborne images, as well as the image calibration and analysis.
The Resource Persons provided their scientific expertise over the entire course of the project duration for designing the field trials, collection and analysis of the field and remote sensing datasets, and for interpretation of results.
The Post-doctoral scholar and the Junior Specialist were responsible for the collection of field data, regular trouble-shooting and maintenance of field supplies and instrumentation, acquisition of remote sensing imagery, as well as specific data processing and analysis tasks.

Goals and Outcomes Achieved

During the course of the project, the research team applied science-based methods and tools for the development of updated information on ET and Kc of mature micro-irrigated pistachio orchards that are beneficial to growers, crop and irrigation consultants, irrigation practitioners, processors and the rural communities of the San Joaquin Valley, where pistachio are among the highest producing crops.
In addition, the project team spent considerable efforts in outreaching and disseminating the updated information on pistachio water use to various stakeholders of the pistachio production community through multiple thematic meetings, field days and workshops. The broad adoption of newly-developed water use information by the pistachio industry could eventually lead to significant water savings, more efficient irrigation scheduling, and to the economic sustainability of pistachio production in the San Joaquin Valley, especially that occurring on salt affected areas. Promoting the adoption of updated water use information will significantly benefit the southern San Joaquin Valley by decreasing water and energy usage, reducing surface and groundwater extractions and degradations, while lowering greenhouse gas emissions, and improving the economic sustainability of rural communities.

The project provided updated water use information of pistachio orchards grown with low volume, high frequency micro-irrigation on non-saline and increasingly salt-affected soils. This information of practical use by the pistachio commodity group were outreached through the usual knowledge-sharing and delivery venues of UC Cooperative Extension, through the California Pistachio Research Board and California Department of Water Resources. Improved water management practices in pistachio production can result from the broad adoption of the updated water use information by the pistachio production community, which in turn can have direct impact on energy use efficiency, as well as on reduction of on-farm water and energy usage, and greenhouse gas emissions.

The project team accomplished most of the goals established for the reporting period. The comparison between the established and accomplished goals of the reporting period are as follows:

Goals Established - Conduct measurements of actual water use (ETa) and determine actual crop coefficients in mature commercial pistachio orchards grown on non-saline and saline soils with micro-irrigation over multiple crop seasons.

Goals Accomplished - ETa was measured and Ka values were determined on four commercial pistachio orchards over the crop seasons 2016, 2017 and part of 2018. Two of these orchards were non-saline and two saline, with a gradient of soil-water salinity conditions.

Goals Established - Investigate the impacts of increasing soil-water salinity on canopy growth and crop ET.

Goals Accomplished - The effects of different soil parameters related to salinity were determined on light interception by the tree canopy and ETa. Functional relations between soil-water salinity, light interception and ETa were derived.

Goals Established - Provide recommendations for optimal irrigation and leaching practices with reduced water availability, and water supplies of different quality, to maintain acceptable root zone salinity levels

Goals Accomplished - Updated information on pistachio ET and crop coefficient along the different stages of the crop season were developed and outreached to the pistachio production community, including pistachio growers, farm managers, crop and irrigation consultants, as well as to representatives from water regulatory community. The updated ET and Kc values for the different stages can inform improved irrigation and leaching practices. However, the project team did not provide recommendation for optimal irrigation and leaching practices, as these recommendations require additional research to better characterize soil-plant-water relations along the different phases of the pistachio crop season.

Goals Established - Conduct outreach activities to disseminate the project outcomes to growers, farm managers and irrigators, and to irrigation and farming consultants.

Goals Accomplished - The project team organized and conducted multiple outreach events to present and disseminate the project results to the pistachio production community and the water regulatory community in California. The project PI was also interviewed by media on multiple occasions and described the project objectives, activities and outcomes. These aspects were outreached broadly to the nut crop production industry in California through media communication venues.

The project team collected field datasets on micro-meteorological and crop parameters, as well as remote sensing information over the crop seasons 2016, 2017 and part of the crop season 2018. These field datasets allowed to determine the actual water use of well-managed, mature pistachio orchards grown with micro-irrigation on non-saline and increasingly saline soils in the San Joaquin Valley of California. Updated information showed about 20 to 30 percent lower consumptive water use than expected by growers based on information generated from earlier studies conducted during 1990’s and early 2000 in sprinkler irrigated pistachio orchards. The collected field datasets also revealed that pistachio orchards grown on saline soils have consumptive water use 10 to 30 percent lower than that of non-salt affected orchards. The broad adoption of the newly-developed water use information will most likely lead to significant reduction in water and energy usage, and in greenhouse gas emissions.

The major successful outcomes of the project are the updated and newly-developed water use information for pistachio production orchards, which are time-sensitive in the prospects of limited and impaired water supplies due to recurring droughts and the enactment of current and upcoming environmental regulations.

Beneficiaries

The information developed during this project are of direct use by the pistachio production community, including individual pistachio growers, farm managers, pistachio farming operations, crop and irrigation consultants, irrigation practitioners, irrigation districts, water coalitions, water resource consulting groups, the

irrigation industry, various agriculture service providers, the California Pistachio Research Board, the California Department of Water Resources, and various farmers' advocacy groups.

The newly-developed information on pistachio water use has been disseminated to 600 beneficiaries among pistachio growers, farm managers, crop and irrigation consultants and various other stakeholders within the pistachio production community. Additional 400 beneficiaries will be reached out in the next few months through extension education and dissemination activities.

Lessons Learned

This project opened multiple venues for further applied-research studies that could build upon the newly-developed information. Good grower collaborators, and the support from the commodity boards of the specific specialty crop being investigated are key for the successful completion of this type of applied research projects.

The project team found out that many pistachio growers do not use advanced irrigation scheduling methods, but only rely on their field experience and on low-technology tools to manage irrigation. In addition, it is also understood that several growers do not keep track of water applications, nor they have a detailed knowledge of the actual performance of their on-farm micro-irrigation systems in terms of average application rates, application uniformity and overall irrigation efficiency.

The project goals were achieved, although the work flow often got unexpectedly delayed for multiple reasons that were not always under the control of the project team. However, an effective project coordination is key for the successful completion of this type of applied research and extension efforts.

Additional Information

A recent publication that stemmed out of this project is available at:
https://www.sciencedirect.com/science/article/pii/S0168192318302259

The agenda, presentations, and recorded videos of the Advances in Pistachio ET and Irrigation management Field Day and Workshop are available at: https://ucanr.edu/sites/PistachioIrrigation/Agenda/

See Attachments 1 – 3

USDA Project No.:	Project Title: Incentives to Reduce Greenhouse Gas Emissions and Nitrate Leaching from Almond Orchards	
41		
Grant Recipient: Almond Board of California	**Grant Agreement No.:** SCB15041	**Date Submitted:** December 2018
Recipient Contact: Gabriele Ludwig	**Telephone:** (209) 765-0578	**Email:** gludwig@almondboard.com

Project Summary

Management options are needed to reduce nitrogen (N) releases as California almond growers are under increasing pressure to reduce N impacts to the air and water. Previous work by the University of California, Davis (UC Davis) identified potential opportunities and it is believed the practices recommended by this research could be turned into a carbon credit protocol, which will allow almond and potentially other woody perennial crop growers to get official credit for these reductions through carbon credits. Carbon credits can reduce the need for additional regulations as well as create a new income stream for growers who sell these credits. Over the past several years, California rice growers developed similar management practices and standards that led to a carbon offset protocol for rice cultivation, which the California Air Resources Board (CARB) adopted in June 2015. Leveraging the knowledge and experience of project partners, this project planned to undertake the following activities: 1) Take components from the rice protocol and the research from UC Davis to develop a carbon offset protocol for use by California almond growers; 2) Develop a cost-benefit analysis for implementing management practices; 3) Pilot the practices with five to 10 growers; 4) Educate 60 to 100 growers on the practices; 5) Develop a plan to scale up implementation with other almond growers; and 6) Identify opportunities to apply the practices to other California woody perennial crops.

Regulated companies in California are under increasing pressure to reduce their greenhouse gas (GHG) emissions. At the same time, almond growers are under pressure to reduce N releases. Developing a carbon offset protocol, as proposed under this grant, growers could be able to generate a revenue stream that will increase in value over time as the limits on GHG emissions increase. Growers who implement the practices recommended by the science and included in the protocol can demonstrate that they are taking action to reduce N leaching and, thereby, reduce the threat of future mandatory N regulations. This project was designed to establish the mechanisms, standards and tools necessary for carbon credit creation, and to provide growers with an ongoing incentive for practice implementation.

This project built upon the 2010 Specialty Crop Block Grant Program Project 47: *Carbon dynamics of orchard floor applied chipped almond prunings as influenced by irrigation methods, soil type, cover crop management and farm practices*. The initial project developed an almond version of the DeNitrification-DeComposition (DNDC) model, a soil biogeochemical model that is highly parameterized to capture and simulate the complex processes that drive carbon and nitrogen cycling, production and consumption of greenhouse gases in the soil and transport of the gas to the atmosphere. The previous project performed initial testing of the model using data from UC Davis field studies; determined carbon sequestration opportunities and losses associated with applying chipped almond prunings to the orchard floor; and determined whether chip application resulted in a valuable accumulation of soil organic carbon in otherwise low organic-matter soil systems. This project was a natural and logical extension of that work and expanded the almond DNDC model by identifying specific practices (based on soil, weather and other factors) that decrease GHG emissions or N leaching using data collected from the Almond Board of California (ABC) and United States Department

of Agriculture Specialty Crop Research Initiative (USDA SCRI) funded research. The practices were intended to be incorporated into a carbon offset protocol that would be approved by the American Carbon Registry (ACR).

The goal was to enable California almond growers who manage their N inputs (to minimize N_2O emissions) to generate carbon offsets and sell those offsets into voluntary and, eventually, compliance markets. An additional benefit of implementing the practices is the reduction of N leaching to groundwater in a region heavily impacted by historic N impacts. Finally, the generation of offsets will allow the agricultural sector to help the state meet its climate change goals and yield long-term, quantifiable benefits. Once demonstrated to be effective on almonds, the principles and framework from this research could be applied to other woody perennial crops throughout California, such as walnuts and pistachios.

Project Approach

The activities and tasks performed during the grant period are as follows:

Activities	Work Accomplished
Activity 1: Review, consolidate and analyze data from the 2009-2013 UC Davis SCRI program on N-Use Efficiency and ABC supported research (such as the California Almond Sustainability Program (CASP)) to identify changes in almond growing practices that can reduce N_2O and NO_3^- emissions.	All data to identify potential almond growing practice changes were analyzed by project partners. As data from UC Davis research became available, the data to identify additional practices that might be adopted to reduce N_2O and NO_3^- emissions was reviewed and evaluated. The project team identified three potential practices for consideration: 1) the reduction in N rate by 10 percent and 20 percent; 2) the use of pumping and fertigating with groundwater; and 3) applying N in the form of a Calcium Ammonium Nitrate Solution (CAN)-17. Unfortunately, the analysis that was performed through the DNDC model did not reliably predict changes in N_2O or NO_3^- emissions for the practices at the field level.
Activity 2: Solicit feedback from almond growers through analysis of data collected through the CASP, as well as by phone, in person and e-mail communications on almond growing practices.	Throughout the grant period, the project team received feedback from growers about the practice and potential interest in participating in a carbon offset pilot project. Grower focus and interest centered on compliance with reporting requirements for the Irrigated Lands Regulatory Program (ILRP). For this program, Water Quality Coalitions throughout the state track N balance on farms with the intent to drive nutrient-use efficiency, thereby reducing GHG. In order to align project efforts with grower data collection and reporting challenges through ILRP, Environmental Defense Fund (EDF) performed a data flow analysis on agricultural GHG data for carbon crediting and compared it with the data required for ILRP reporting. It was found that the majority of the data collected for ILRP could be used to generate carbon credits. In addition, EDF has ongoing work to develop a tracking and reporting framework that graphically shows a grower their N balance (N-Balance) and compares them to their neighbors. N-Balance is a

	simple input-output model that calculates the amount of N leaving a field based on reliable data about inputs (fertilizer) subtracted by outputs (yield, prunings). The remaining value is the N lost to the environment. It is believed that this framework could use ILRP data to provide growers with additional information and metrics on how to improve their performance relative to other almond growers with similar yield and soil properties.
Activity 3: Finish calibrating and validating DNDC model for California almonds using existing field data from ABC, CARB, California Energy Commission, California Department of Food and Agriculture, Fertilizer Research and Education Program (CDFA FREP) and fertilizer industries.	The DNDC model was calibrated and validated using the same data sets used in Activity 1 to identify practices to reduce N_2O and NO_3^- emissions. As a part of developing a carbon offset protocol with the ACR (Activity 7), DNDC-Applications Research and Training, LLC completed an uncertainty analysis of DNDC modeling for almonds. Unfortunately, the model results indicated that the DNDC model does not currently reliably predict changes in N_2O and NO_3^- emissions for the identified fertilizer practices for almond cultivation at the field level. Nevertheless, UC Davis has an additional year of data from their research on practices to reduce N_2O and NO_3^- and project partners have discussed data-sharing with UC Davis to add this data to the model to improve its performance after the conclusion of this grant. The goal of the uncertainty analysis was to demonstrate the correspondence between DNDC-simulated and field-measured N_2O emissions from almond management in four different orchards. When emissions from baseline management are aggregated, DNDC-simulated growing season emissions are comparable to field measured (0.73 (modeled) to 0.83 (measured) kgN_2O-N/ha). Furthermore, mean baseline emissions correspond well to a separate DNDC study using a different methodology (0.73 (modeled) to 0.86 (measured) kgN_2O-N/ha; Deng et al, 2016). These two comparisons indicate that there is reasonable correspondence in aggregate. Unfortunately, at the site level, comparisons were incongruent. In an ideal set of simulations, DNDC would replicate field-measured changes to N_2O based on changes to management – or would at least show N_2O changes in the same direction. The incongruence between modeled and measured values was related to numerous factors, including DNDC's simulation of nitrate leaching (not measured at any of these sites) and its influence on soil N concentration, the calibration methodology for perennial woody crop yields (problematic with DNDC's annual crop-based philosophy), sub-

	orchard management differences (tree rows versus alleys) and DNDC's lack of lateral transport of water and nutrients. In prior validation studies, DNDC has simulated N_2O well in California, under both perennial and annual crops, such that CARB has been using DNDC for their Statewide N_2O Inventory. Therefore, because of DNDC's performance in aggregate in the present validation study and the small number of sites simulated, including additional sites/studies in future validation efforts for almonds, would be worthwhile and beneficial; project team knew of several studies in-progress and have discussed data-sharing with UC Davis researchers. Alternatively, DNDC-simulated N_2O could be validated across multiple crops (e.g. almonds, vine crops, other tree crops), thereby incorporating more studies as a way to generally demonstrate DNDC's effectiveness for perennial woody crops.
Activity 4: Develop cost-benefit analysis tool for implementing changes to growing practices - taking into account fertilizer costs/savings, grower time, offset revenue and volume of N_2O reductions.	A final draft of the cost-benefit tool was completed and presented to project partners. Feedback and feature requests were addressed and implemented. (Please see attachment 2)
Activity 5: Develop communication and training materials and surveys for outreach events and/or webinars focused on educating almond growers about practices to generate N_2O and NO_3^- reductions, the different markets available to growers (AB32, CEQA, National Environmental Policy Act), the revenue that can be created by the grower, how to use the cost-benefit tool and offset protocol and the opportunity to demonstrate and communicate reductions in nitrate leaching.	Project partners determined a list of recommended practices. However, the results of the uncertainty analysis shed doubt on the ability to recommend field level practices. As a result, the project team halted this work until they were confident with practices that could reliably reduce N_2O and NO_3^- emissions at the field level.
Activity 6: Conduct regional analysis to determine mitigation potential of practices. Results of this analysis will provide growers and project partners with	The results of the regional analysis are included in Attachment 1.

estimates of economic potential of ideal practice combinations.	
Activity 7: Develop a carbon offset protocol for California almonds. This will include formatting the DNDC model for inclusion in the protocol and establishing the structural uncertainty of the model. The protocol would be developed so that it can be quickly and seamlessly adopted by CARB for use under AB32, similar to the process to adopt the rice protocol.	The ACR made significant progress updating their respective fertilizer carbon offset protocols. They are finalizing updates to their *Methodology for Quantifying Nitrous Oxide (N_2O) Emissions Reductions from Reduced Use of Nitrogen Fertilizer on Agricultural Crops*. ACR's protocol is pioneering the use of the "umbrella protocol" approach, developed by EDF, UC Davis and the University of Vermont. This approach will eventually allow the protocol to include almonds. During summer and fall 2018, this version underwent public and peer review, and ACR expects to publish the final version early 2019. Unfortunately, the aforementioned DNDC modeling uncertainty results limit the reliable prediction of emission reductions in almond production and prevent it from being included in a protocol at this time. However, the framework of the ACR protocol will allow for the adoption of an almond N_2O reduction module once the model uncertainty is resolved. Project partners continued discussions with CARB to keep them updated on the progress of protocol development and continued to advocate for CARB's inclusion of additional agricultural protocols in their cap-and-trade program. Because CARB is focused on adopting changes to the regulations to extend the cap-and-trade program to 2030 consistent with AB398, they will not be able to start a regulatory rulemaking to include new agricultural offset protocols before 2019.
Activity 8: Hold outreach events and/or webinars to recruit growers to participate in a pilot project to implement the practices identified by UC Davis and obtain feedback on the protocol and cost-benefit tools developed under this grant. These outreach events and/or webinars will help increase grower knowledge about opportunities to generate N_2O and NO_3 reductions, identify opportunities for growers to engage in the process and solicit feedback on how to make the practices and tools more attractive to the growers in future	The project team conducted the first outreach event with growers at the 2017 Annual Almond Conference from December 5–7, 2017. During the "What's New in Almond Tree Nutrition and Regulation?" panel discussion, and in a one-on-one poster session, the project team solicited feedback from growers on the cost-benefit tool developed in Activity 4; they also encouraged growers to participate in a pilot project. While valuable feedback was obtained on the tool and general interest was expressed by growers, no growers showed sufficient interest to justify a detailed follow up. More than 100 growers, consultants and researchers attended EDF's "Potential for Carbon Credits from Improved N Management" panel discussion at the Conference, thereby increasing grower knowledge about the practices that are likely to generate N_2O and NO_3^- reductions. The discussion also re-energized collaboration potential between EDF and California's regional Water Quality Coalitions for data collection and reporting efforts.

outreach. Team will travel to locations convenient to growers.	As discussed with CDFA FREP, be use of the results of the uncertainty analysis of DNDC, the project team decided not to conduct additional outreach events and instead focused on analyzing new research data for inclusion in the DNDC model and furthering development of offset protocols to enable them to accept an almond module in the future.
Activity 9: Develop a pilot project with five to 10 growers using practices determined through research under the grant that will include supporting growers on the technical details of implementing the practices, collecting the necessary data to generate a carbon offset and supporting the grower in using the cost-benefit tool. Travel to orchards where projects are implemented to visit with growers.	Because of the uncertainty analysis of DNDC and in consultation with CDFA FREP, the pilot project was not developed. Instead, the project partners focused on analyzing new research data for inclusion in the DNDC model and furthering development of offset protocols to enable them to accept an almond module in the future. This analysis was not completed by the end of the grant but will continue by DNDC-ART and UC Davis.
Activity 10: Obtain approval of almond offset protocol by the ACR. Process includes conducting public outreach events and/or webinars and a peer review of the protocol module by independent experts. The public outreach events and/or webinars will include stakeholders interested in offset protocols in general and California almond growers specifically. The project team will proactively solicit feedback from growers directly and through the ABC Environmental Committee. The peer review will include an independent analysis and detailed technical questions from experts in the field of carbon N cycling and offset protocols. Peer review typically requires two to three rounds of feedback.	See progress under Activity 7, above.

The project did not benefit commodities that were not specialty crops.

All project partners have made significant contributions to this project.

EDF coordinated project meetings and progress towards deliverables by facilitating conversations among project partners and external collaborators to accomplish proposed goals around protocol development and outreach material development. They also led the creation of the economic tools which allow growers to analyze the practices that work best considering this climate and soil type. This tool was shared with growers as well as with SureHarvest who leads ABC's CASP program. A copy of this tool is provided with this report.

UC Davis provided data from the Madera and Nickels sites to DNDC-ART. However, insufficient data exist for those sites for the project team to perform a similar statistical modeling procedure as was performed for Belridge/Lost Hills.

DNDC-ART completed the creation of a comprehensive and harmonized database of daily field measurements from the Madera, Belridge, Nickels and Davis, California almond orchards. Using this database, DNDC-ART performed a calibration and validation of the model with eight site-years of field data. The complete methodology is listed in Attachment 1.

DNDC-ART also completed DNDC-model simulations of California almond orchards; the study simulated hypothetical baseline management, numerous N management strategies (reduced N applications, changes to N form, N application timing and groundwater N testing and accounting) and multiple irrigation water application methods. A detailed methodology and statewide results are listed in Attachment 1.

Goals and Outcomes Achieved

Expected measurable outcomes	Target	Actual outcomes
Outcome 1: Additional revenue is generated by almond growers through carbon market.	Five to 10 California almond growers participate in a project to generate voluntary carbon offsets. Before this project can be scaled up to all California almond growers, it must be piloted with a small group. Long-term, these credits will be possible to sell on voluntary or compliance markets.	The benchmark for this target was zero since there is current no offset protocol to allow growers to participate. Due to the uncertainty analysis of DNDC, the project team was unable to develop a pilot project.
Outcome 2: Almond growers acquire knowledge and skills necessary to reduce N inputs and expand stewardship practices for use beyond the grant duration.	Educate 60 to 100 growers.	The benchmark for this target was zero. Since there is no standard that exists that allowed growers to measure impact changes and generate revenue. Using ABC's N calculator, the project reached out to more than 600 growers

		throughout the duration of the project. The project team then used what was learned from those conversations to continue to update the education materials and cost-benefit tool for N management.
Outcome 3: Almond growers implement N-efficiency practices outlined in a carbon offset protocol as a result of the development of tools, infrastructure and education conducted through this grant.	ACR approval of a voluntary carbon offset protocol by December 2017.	Prior to the project, there was no carbon offset protocol for almond growers to implement N-efficiency practices. ACR was not able to publish the updated protocol during summer 2018. However, guidance and procedure documents and the errata and clarification document for their methodology were published. While the protocol will not initially include almonds, it will provide the framework to add an almond module once the uncertainty for management practice reductions can be minimized.

This project furthers the development and understanding of potential practices almond growers can implement to reduce N loses to the air and water. It also supported the establishment of a modular fertilizer protocol which will help growers of any specialty crop participate in the carbon market once there is adequate scientific data on the practices and a model that can calculate the environmental benefits of implementing a practice at the field level.

In addition, relationships were deepened with the Regional Water Quality Control Board (RWQCB) and CARB by educating them on the leadership the almond industry is demonstrating in the search for opportunities to reduce N loses to the environment from the cultivation of almonds in California.

Finally, project partners developed economic and geographic information systems (GIS)-based tools that allow growers to better understand and calculate the environmental benefits of implementing the N-loss reducing practices identified through this grant.

Prior to this grant, no work had been conducted to identify activities that could reduce N losses with almonds. This grant 1) identified practices that have scientific data supporting the reduction of N losses; 2) developed a framework protocol that will allow for the addition of almond practices once the DNDC model can accurately calculate N fluxes at the field level; 3) furthered the leadership of almond growers in addressing critical environmental concerns with regulatory bodies, including CARB and RWQCB; and 4) developed economic and GIS-based tools that allow growers to better understand and calculate the environmental benefits of implementing the N-loss reducing practices identified through this grant.

Major successful project outcomes:

- More than 100 growers, consultants and researchers attended EDF's "Potential for Carbon Credits from Improved N Management" panel discussion at the 2017 Annual Almond Conference from December 5–7, 2017. Through this effort, grower knowledge was increased regarding the practices that are likely to generate N_2O and NO_3^- reductions. The discussion also re-energized collaboration potential between EDF and California's Regional Water Quality Coalitions for data collection and reporting efforts.
- Using ABC's N calculator, the project team reached out to more than 600 growers to increase their knowledge about the practices that are likely to generate N_2O and NO_3^- reductions.

Beneficiaries

Growers: Almond growers increased their knowledge about the practices that are likely to generate N_2O and NO_3^- reductions. Between 600 and 700 growers increased their knowledge about the practices that are likely to generate N_2O and NO_3^- reductions.

Researchers: Researchers at UC Davis increased their knowledge about the practices that are likely to generate N_2O and NO_3^- reductions. They also furthered their knowledge about the ability of the DNDC model to calculate N fluxes at the field level.

Regulatory Agencies: Regulators at the RWQCB and CARB learned more about the leadership the almond industry is demonstrating in the search for opportunities to reduce N loses to the environment from the cultivation of almonds in California. Five regulators at the RWQCB and CARB learned more about the leadership, and the almond industry is demonstrating in the search for opportunities to reduce N loses to the environment from the cultivation of almonds in California.

Offset Registries: Both the ACR and CAR understand the potential practices that reduce N loses to the environment from the cultivation of almonds in California. They also understand the current uncertainty limitations to the DNDC model for its potential use in their carbon offset protocols. Six employees at the ACR and CAR understand the potential practices that reduce N loses to the environment from the cultivation of almonds in California. They also understand the current uncertainty limitations to the DNDC model for its potential use in their carbon offset protocols.

Lessons Learned

Challenge with Models: Field measurements are critical no matter how you use models. They are required to validate the model results or develop emissions factors. Even with all the data that has been collected on almonds, there is still not enough information to robustly use models for environmental markets. DNDC-ART found that the uncertainty of their model exceeds the calculated reductions and was therefore not able to be used to develop a carbon credit protocol for almonds. All models would benefit from additional N_2O field measurements and the project team encouraged the state to continue its support of field-level N-loss research.

As a result of many of these challenges, EDF is pursuing N balance as an approach to provide producers with feedback on the efficiency of their operations. There is robust evidence of a relationship between N balance (N inputs minus N outputs) and N_2O and NO_3^- emissions. There are efforts underway to develop measurement curves to calculate N_2O and NO_3^- emissions based on a producer's N balance metric. Once those curves are developed, it would be possible to modify an existing protocol to use N balance, rather than

one of the biogeochemical models, to calculate N_2O emissions.

Protocol Development: The development of protocols is a deliberate process that relies on scientific data. The necessary field data to determine what practices reduce N_2O and don't have corresponding environmental impacts takes years to develop. Once that data is collected and analyzed, they must be put into biogeochemical models that can be tailored for use in offset protocols. The biogeochemical models have large uncertainties due to their limited datasets and the variable nature of agricultural processes. As a result, it takes a long time to develop protocols and update.

DNDC-ART conducted an uncertainly analysis of predictive DNDC modeling for almonds. From the review of the results, project partners determined that the DNDC model is not able to reliably predict changes in N_2O emissions reductions for select practices in almond cultivation. This is because the uncertainty results are greater than the reductions for the implemented practices at the field level. While it is understood that progress continues to be made toward establishing N_2O and NO_3^- quantification methods and associated uncertainty analyses, the DNDC model is not yet ready for consideration in the measurement of N losses at the field level.

Because of the uncertainty analysis from DNDC, pilot project was not developed. Instead the focus shifted on to analyzing new research data from UC Davis for inclusion in the DNDC model to reduce the model uncertainty and further the development of offset protocols to enable them to accept an almond module in the future.

Additional Information

DNDC-ART is in the final stages of completing a journal article which contained two objectives: (i) simulate a range of N management practices across a broad range of physical conditions (climate and soils of California's Central Valley) and (ii) assess N_2O mitigation potential through a comparison of alternative management scenarios against a "conventional" baseline that includes the most common practices in US production with an eye toward either beneficial or neutral effects to N leaching and yield. This manuscript was submitted to Agricultural Systems and is expected to be published by the spring of 2019.

"Assessment of orchard N losses to groundwater with a vadose zone monitoring network," 2016.04.12, Agricultural Water Management 172, 83-95
https://www.sciencedirect.com/science/article/pii/S0378377416301299

"Estimating Nitrate Leaching to Groundwater from Orchards: Comparing Crop Nitrogen Excess, Deep Vadose Zone Data-Driven Estimates, and HYDRUS Modeling,"
2016.07.18, Vadose Zone Journal 15 (11)
https://dl.sciencesocieties.org/publications/vzj/abstracts/15/11/vzj2016.07.0061

"Defining a best practice methodology for modeling the environmental performance of agriculture," 09.2018, Environmental Science & Policy. Volume 87, Pages 64-73.
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CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 42	**Project Title:** Sustainable Water Management Strategy for Specialty Crop Expansion in the Sacramento Valley	
Grant Recipient: Sacramento Area Council of Governments	**Grant Agreement No.:** SCB15042	**Date Submitted:** December 2018
Recipient Contact: David Shabazian	**Telephone:** (916) 340-6231	**Email:** dshabazian@sacog.org

Project Summary

Water management strategies greatly influence the continued competitiveness of California specialty crop production both on and off the farm, an issue of growing importance, due not only to sustained drought conditions, but also recent cropping pattern changes responding to market signals. Over the past decades, California farmers have invested in irrigation technologies to improve performance; less understood is how this adoption can also alter the existing ecosystem services of regional agricultural systems. This project sought to address these challenges through enhanced modeling, tools, and analytics. This project developed a modeling tool to identify strategic flood irrigation scenarios exclusively on specialty crop lands in the Sacramento Valley that preserve habitat and maximize aquifer recharge for specialty crop production, which currently meets about 30 percent of its water use from groundwater.

The project was both important and highly timely given the record low rainfall in the last several prior, and the growing concern around water use in agriculture. In general, as drought conditions persisted, so too did the need for new tools and strategies that showcased production without resource depletion. This was especially as new state groundwater legislation was scheduled to take effect.

This project is a complement to the work from the 2011 Specialty Crop Block Grant Program (SCBGP) Project 39: *Food Bank as Food Hub: Building a Local Food System*, which delved into the economics of infrastructure to support specialty crops produced for the local market. Through this original grant, the project staff noted the substantial economic returns of local specialty crop production yet also the correlation between agricultural value and water consumption. The project also noted the expansion in harvested acres of export-oriented specialty crops such as walnuts and locally-serving fruits and vegetables in the Sacramento region, presaging the need to better understand the environmental effects of this cropping change. In short, the work of the 2011 SCBGP Project 39 called attention to the tradeoffs in production decisions and the need for future work to better understand, develop and implement beneficial management practices that improve both farm viability as well as the environment. This project has added the important component of soils/hydrology/ hydrogeology in an ecosystem service capacity into a tool that the Sacramento Area Council of Governments (SACOG) region can use to take a more in-depth look at economic returns in consideration of how to grow and increase the amount of specialty crop production in the region.

Project Approach

Technical and data related tasks included: Reviewed existing and emerging irrigation systems and technologies. Compiled per acre metrics of irrigation strategy by specialty crop including acre feet, supported crop densities and water source.

- Dominant irrigation system types were estimated for each irrigation or water supply district. The majority of districts are predominately using surface/gravity irrigation; however, specialty crops may not reflect this proportion. It is estimated that approximately 20 percent of the land

area in the study area has changed from surface irrigation methods to low-flow irrigation methods in the last 25 years. Estimated applied water for each specialty crop within the SACOG region in 2014 was calculated for each primary irrigation type. Applied water depends on both the crop's water requirement and irrigation efficiency of irrigation systems. Typical yield values for each specialty crop were compiled for this report; however, there is little research on the impact of increasing applied water. Multiple University of California (UC) recharge field studies are ongoing for almonds and pistachios but those results have not been published yet. Survey information from field agronomists and farmers in the San Joaquin Valley, California has been collected and developed to estimate recharge water in excess of crop water demand that could be applied at different periods of the year/crop cycle; however, this information is preliminary and will likely be updated and modified as more experience and information accumulates. Surface water availability was reviewed for irrigation districts within the SACOG region which have specialty crops and where groundwater recharge potential was evaluated. Information was obtained through review of Agricultural Water Management Plans. For some districts, only qualitative information on water rights was available.

Documentation of changes in irrigation techniques by regional specialty crop producers:

- The Tindula et al. (2013) results, when adjusted to a 25-year period and accounting for the lower rate of change in the 2001 to 2010 period, suggest that approximately 20 percent of the land area in the study area has changed from surface irrigation methods to low-flow irrigation methods in the last 25 years.

Reported soil type permeability, both lateral and vertical. Created GIS layer joining permeability data to soil dispersion:

- Subsurface (hydrogeologic), surface and crop suitability recharge suitability indices were developed and applied to the SACOG region to evaluate poor, fair, and good potential for recharge. The subsurface index indicated that areas that have the greatest potential for recharge from a hydrogeologic perspective are in the southeast portion of the SACOG region in the Cosumnes and South American Subbasins. There are also limited areas in western Yolo Subbasin, the North American Subbasin, North Yuba and South Yuba Subbasins, and in the Sutter and East Butte Subbasins near the Sutter Buttes that have good potential for recharge. These areas shrink under wet conditions and swell under dry conditions.
- Applying the Soil Agricultural Groundwater Banking Index (SAGBI) to the SACOG region, good and fair areas were indicated along the eastern side of the study area as well as some on the western side. However, the central portion of the SACOG area from north to south was indicated as a poor area for recharge considering soils. Combining subsurface and surface indices narrowed the areas with good recharge potential. Areas with both good surface and subsurface suitability are primarily in the central and southern portions of Sacramento County, central portion of Yolo County, along the Sutter Buttes, and in the wester portions of placer and Yuba Counties.
- Specialty crops in the SACOG region were evaluated for recharge suitability considering degree of tolerance to saturation, dormant period length, and nitrogen requirement. Apples, grapes, pears, and plums/dried plums were the highest rated for recharge potential, while almonds, kiwi

fruit, pistachios, pomegranates, and walnuts were rated fair. Idle (fallow) land was also considered good for recharge since specialty crops can potentially be established on it.

- Good ratings were noted for hydrogeologic, soil and crop suitability converge in the southern portion of Sacramento County, central portion of Yolo County, along the Sutter Buttes, and near the intersection of Yuba, Placer, and Sutter counties. The total acreage of good ratings in the final recharge index was 32,179 during wet conditions and 42,345 acres during dry conditions. Approximately 37 percent of the fields with good ratings were idle while the remainder were primarily almonds, walnuts, grapes, plums, prunes, or apricots. Throughout the study area, specialty crop fields with good overall potential for recharge were limited and scattered compared to the total specialty crop acreage.
- Surface water suitability was not included in this evaluation at this time because of the scarcity of information available on surface water availability.
- Model water demand of current specialty crop production in region (project's base case scenario).
- Model water supply for specialty crop production under a series of precipitation and irrigation scenarios.
- Model economic effects of specialty crop expansion under sustainable water supply scenarios.
- Integrate ecosystem service in Rural-Urban Connections Strategy (RUCS) model.
- Model ecosystem services for specialty crop acreage under variety of supply and demand conditions.

Scenario Modeling components of the project: In summary, The SACOG region has nearly 350,000 acres of agricultural land in suitable recharge areas; nearly 170,000 acres of this land could be flooded for recharge with the specialty crop currently produced there. Unlike high-cost infrastructure projects like dam construction or expansion, groundwater recharge takes advantage of the vast water storage capacity that already exists underground. Farmlands are also likely to already have the water conveyance infrastructure necessary to divert recharge water, which non-agricultural open space lands may lack. As California's population continues to grow and open lands are developed, multi-benefit working lands management becomes increasingly important to maximize beneficial outcomes and help growers resist development pressures. Agricultural flooding during the winter allows growers to divert peak flows when water is more abundant, relieving stress on levee infrastructure and achieving habitat co-benefits for pacific flyway waterfowl and other wildlife species.

The scenario results highlight the potential for growers in the region to engage with Groundwater Sustainability Planning efforts and leverage their land to help ensure the resilience of these resources that are so critical to their businesses. Annual specialty crop lands grown on suitable soils provide the greatest recharge potential of the identified specialty crops, however— with the exception of tomatoes— these crops do not currently represent a significant acreage in the region. While crop constraints limit the recharge capacity of orchard and vineyard crops, compared with annual specialty crops, these croplands are still able to generate recharge. Several of these crops represent a large percent of the region's current crop acreage; walnuts, almonds, and wine grapes alone make up one quarter of the acreage in good and fair recharge areas. If even a portion of farmers these crops engaged in, recharge flooding across a large area, the region could see significant recharge benefit, even in spite of the lower of recharge per acre. The permanent water demand of established orchard and vineyard crops means that these growers are likely to have the greatest interest in

restoring aquifers and increasing water supply reliability, which may increase the prospect of on-farm recharge participation.

With full grower participation and adequate water supply, the region's growers could restore twice as much water as their crops would need for irrigation. The region's booming agricultural economy is driven by specialty crop production, which offers high returns to growers and generates significant value for the local economy. This study highlighted the opportunity for these specialty crop growers to leverage the potential of their land in a new and important way. By helping to restore aquifers and improve reliability of groundwater supplies, growers can help to safeguard the resilience of this critical resource and the agricultural economy that it underpins.

Outreach Related Tasks: Build outreach list of key specialty crop stakeholders:

- SACOG staff and the consultants made use of Northern California Water Association stakeholder list which spans from local growers, to researchers, to water purveyors, and various jurisdictional staff. Targeted communications and meetings were set up within the SACOG six county region geography to provide input during the study, develop scenarios, and share results.
- Initial outreach to the University of California Cooperative Extension (UCCE), growers, and other stakeholders. Stakeholders provided feedback on research results and extent of adoption in region.
- Updated project research results based on stakeholder and advisory committee input.
- Held workshops of results to gain feedback form key stakeholders.
- Assembled final report and conduct final workshop; report to SACOG Board.
- Presented findings to stakeholders and local jurisdictions.
- Incorporated feedback and finalize sustainable management models.
- Conducted project outreach and advisory committee meetings:
  -Meetings were held in Sacramento to kick off with stakeholders
  -Willows, California to provide overview of initial results
  -Marysville, California representing Yuba, Sutter, and Placer counties
  -Sacramento, representing South Sacramento County
  -Woodland, California representing Yolo County
- For each region, SACOG and partners invited water managers from irrigation districts and county government along with agricultural leaders and ag advisors including Farm Bureau, UCCE, County Agricultural Commissioners, and local non-profit resource management professionals. This was a ground-truthing to assess local interests and concerns about groundwater supply and recharge opportunities and current cropping.

This project did not benefit commodities other than California specialty crops.

Project partners at the Northern California Water Association and county Agricultural Commissioners within the SACOG six-county region played an instrumental role in stakeholder engagement. Partnering with these entities enabled the project staff to reach a wider range of diverse stakeholders, including a large number of local growers from across the region, local water managers, and UCCE advisors. The project staff was able to share initial findings and get substantive input on geographic specific questions related to conveyance, crop trends, and data accuracy related to technical findings on fixed factors such as soils/hydrology/hydrogeology.

Project Partners helped to facilitate the project staff to work with existing groups and committees providing a means to validate the results of the groundwater suitability recharge index, inform scenarios to model, and to ensure that plausible scenarios were developed and modeled to obtain meaningful outcomes.

Goals and Outcomes Achieved

In executing Outcome 1, the project staff compiled a comprehensive range of datasets, including groundwater level data and basin readings, to evaluate groundwater recharge feasibility and potential on specialty crop lands. This hydrologic and hydrogeologic information was integrated with SACOG's cutting-edge toolkit for agricultural and economic analysis, which was updated with the most timely and recent data on specialty crop production in the study and relevant cost and return metrics for the identified specialty crops. The project staff compared precipitation levels over time to establish two representative baseline conditions that reflect periods of low precipitation and higher precipitation, respectively, which provides a benchmark for understanding how a given year compares with typical historic patterns specific to the study area region for utilization by SACOG and local stakeholders.

In execution of Outcome 2, project staff worked to update SACOG's inventory of crop data to reflect the most up-to-date metrics and information for specialty crops available. In addition to production data and reported information such as county crop data, the project staff updated crop map data through an aerial imagery-derived dataset. This information was integrated with the RUCS analytical toolkit to identify a comprehensive range of scenario-specific metrics on agricultural costs and returns, as well as inputs such as labor demand, irrigated water demand, etc. Through an ongoing series of outreach meetings and communications in the stakeholder engagement process, project staff worked with growers and local agricultural stakeholders to ground truth and refine these results, based on local knowledge. The project staff will continue to update and monitor these datasets in an ongoing manner to evaluate the success of these specialty crop enhancement strategies and the attainment of long-term outcomes.

The outcome measures of this project reflected long-term goals to address the large-scale scope of the challenge facing growers and water managers in the region in pursuit of sustainable use and replenishment of groundwater supplies, as well as increased value of specialty crop production in the Sacramento region that these recharge efforts will support through improved water supply reliability. However, this project demonstrated progress toward these long-term objectives. As identified in the prior response, this project built expanded and enhanced SACOG's repository of high quality information that will be updated in an ongoing fashion, to monitor ongoing success based on the identified performance metrics, including improvements in agricultural value and replenishment of agricultural groundwater resources. Through the stakeholder engagement process, staff strengthened relationships with not only farmers, but also regional water managers and other stakeholders involved in the development of local Groundwater Sustainability Plans, as mandated for each hydrologic basin in California. The data and scenario analysis developed under this project will be available for utilization by these local stakeholders to enhance their groundwater sustainability plans, improve recharge strategies, and reduce the likelihood of curtailments to agricultural water use by specialty crop growers in the region. Additionally, the stakeholder engagement process opened up new lines of communication between SACOG, local growers, and water managers to engage in a productive dialogue and work together to ensure that growers have a reliable water supply going forward.

The project staff were successful in accomplishing the identified goals for this project. The project staff worked to finalize cropping scenarios that test a variety of different flooding and cropping conditions to identify the potential for increased recharge and economic growth. The project staff presented these results to stakeholders, including growers and water managers at the Northern California Water Association's quarterly meeting, in order to share preliminary findings with stakeholders working on these issues on-the-ground. SACOG staff additionally summarized project results that were reported to the SACOG Board of Directors' Land Use and Natural Resources Committee. In order to reach a broad and ongoing audience, the project staff recorded a webinar wherein the project contractors who provided scientific and subject-area expertise on agricultural recharge suitability detailed the methodology, analysis, and stakeholder feedback that went into this project. This recorded webinar presentation is available on SACOG's website and will enable a much broader range of local farmers, planners, water managers, local decisionmakers, and other stakeholders to access these findings in a clear and explanatory manner into the future. SACOG additionally created a StoryMap to present the project work. This platform offered a sleek and engaging way to walk stakeholders through the process of identifying areas that are ideal for recharge on specialty crop farms based on a range of complex factors, in a simple and easy-to-understand manner. This interface links to webinar video clips that allow the viewer to delve into more of the technical details of the project. The project staff successfully created a multimedia approach that will enable dissemination project findings to each of the interested audience, providing a tailored display of project findings for readers at any level of expertise.

The project staff updated SACOG's inventory of crop data with the newest reported specialty crop data that were released during the course of the project, including information from the Crop Reports released by each county Agricultural Commissioner in the SACOG six-county region, as well as compiled reporting of these datasets for each county in California that are aggregated annually by the California Department of Food and Agriculture, and are available in tabular format through the United States Department of Agriculture National Agricultural Statistics Service. The project staff has monitored these data as an indicator of specialty crop value and increasing values and will continue to track these data as an indicator of progress toward the identified targets.

A range of hydrologic datasets on a diverse array of factors were utilized to refine and truth a depth to groundwater data layer with comprehensive coverage for the entire study area that represented each wet and dry conditions. Groundwater elevation data were collected and compiled from the California Department of Water Resources through the California Statewide Groundwater Elevation Monitoring program and Water Data Library and from the United States Geological Survey through the National Water Information System. In total, groundwater elevation data were available for over 3,500 wells in and around the Study Area, of which approximately 1,000 are actively monitored. Groundwater elevation data from these wells were compiled into a unified database and reviewed to assess groundwater elevation trends by subbasin, prepare selected groundwater surface contour maps, and estimate Study Area-wide depth to water. In addition to these more comprehensive datasets, SACOG staff will continue to leverage GIS data available from the California Department of Water Resources through the Groundwater Information Center Interactive Map Application which allows staff to easily monitor changes in groundwater levels in the region in an ongoing manner and compare these to current land use and cropping patterns.

Outcome 1: Increase in groundwater storage by 50,000 acre-feet in above-average precipitation years and to slow groundwater depletion by 35,000 acre-feet a year in below-average precipitation years.

Compared with the originally identified baseline of 2013, the average groundwater elevation for the full study area increased approximately 1.11 feet by the conclusion of the project period in 2018. The average increase in groundwater elevation 0.55 feet over that period was for specialty crop lands examined in the study, or an estimated 251,455 acre-feet of net recharge. This amounts to approximately 50,290 acre-feet of net recharge annually over this period. The majority of this observed increase occurred during the project study period. In the course of the project study period, between 2015 and 2018, the average groundwater elevation for the full study area increased by an average elevation of 5.18 feet. By comparison, the average groundwater elevation for the specialty crop lands that were examined in this study grew 6.32 feet on average.

Outcome 2: Expand dollar value of specialty crops produced in the Sacramento region by $25 million a year. Compared with the originally identified crop year baseline of 2012, specialty crop farmgate value in the study area increased $199,553,597 over the course of the study period between 2012 and 2017, in inflation-adjusted 2017 dollars. This increase in combined value of fruit and nut crops, vegetable crops, and nursery crops amounted to an average of $39.9 million annually. Fruit and nut crops-- which were the primary specialty crops that this study focused on-- increased in value by $172 million over that period, amounting to an average of $34.5 million per year

These results exceeded the established target measure identified for the project, which estimated that compared to the baseline, the project expected an increase in specialty crop production in the Sacramento region of $25 million a year in inflation-adjusted dollars.

The successful outcomes of this project are long-term in nature. However, the region has already seen growth and improvement on each of the identified progress-areas. Data for the 2017 cropping year is still unavailable, however between 2015 and 2016, the region's specialty crop farmers experienced an increase in farmgate over $104 million across fruits, nuts, vegetables, and nursery crops, representing a 9 percent increase in value over the previous year. Fruit and nut crops saw an increase in value of 12 percent over the prior year, representing an increase in value of over $97 million. Groundwater basin levels showed similar improvements through the course of the project. From 2014 to 2017, observed autumn measurements of groundwater levels increased by 7.84 feet on average across the study area, and increased an average of 3.99 feet in Spring measurements. These indicator metrics are each influenced by a range of factors which present a broad challenge in identifying causal linkages, however these metrics indicate promising trends in enhanced value for specialty crops and increased groundwater supply reliability that will help to ensure the ongoing success of local specialty crop production and the related economic activities associated with this sector, including value-added processing.

Beneficiaries

SACOG is a joint powers authority made up of six counties and 22 cities. Through the RUCS program, these jurisdictions and their associated water districts and other water resources entities have been engaged in the development of this report and will benefit from its findings and tools. As well, farmers will have access to the project results, which provide strategies for land use and land management practices that can maximize groundwater recharge. All these stakeholders can use the study for purposes of complying with the state’s Sustainable Groundwater Management Act.

There are roughly 7,200 farms in the SACOG region that depend on sustainable water resources and would therefore benefit from this study and the tools provided. There are also over 90 specialty crop-based food

processors in the region that depend on sustainable crop production, which in turn needs reliable water supplies that can be enhanced by findings in this report. Both the on-farm and off-farm components of the food industry account for at least 30,000 jobs, which may be affected by the information and tools provided by this study. As well, there are countless consumers that buy locally grown food, who may be impacted by implementation of strategies suggested in the study.

Lessons Learned

This project was successful in pulling in a new stakeholder group and giving them a new focus on the potential of specialty crops as place for both recharge and ecosystem services. Much more research can be completed to look at this same study in new and different ways. In a way, project staff were limited by the amount of funds that were available. The project staff shaped the research done by the consulting team to fulfill the purposes of the grant but noted that many more variables could be considered by someone who will do future work.

The data that has been produced has been requested by several GSAs as it can provide a building block for the work that they will be doing in the future. Similarly, it provides a starting point for regional consistency. A challenge for the finding of this research was the willingness of growers to flood specialty crop fields, particularly growers further North of California in the study area who faced less constraint on combined surface and groundwater availability. In the stakeholder outreach sessions, interest in general, pointed to a willingness to flood in areas such as unlined canals or adjacent to crops. Also, depending on geography within the region, areas with an abundance of water identified as less willing to participate. One reason identified that contributed to a reluctance toward flooding on high-value permanent orchard crops, such as fruits, nuts, and vineyards, was the lack of data and research on how crop yields may be impacted and whether winter-flooding may impact the long-term health of the plants. A growing number of research projects are being undertaken to evaluate the impacts of on-farm flooding programs and the impact that these practices may have on crops, particularly in the southern San Joaquin Valley where groundwater overdraft was more severe and almond and other growers have partnered with researchers aiming to answer this question. As this body of data continues to build and the impacts, or lack thereof, are better understood, some stakeholders indicated that grower willingness to flood orchard fields within the study area may increase.

Groundwater recharge is challenging in that when conditions are optimal for recharge, during wet season with available water, the aquafer areas are at their fullest. Similarly, in the dry season, there is a lack of water available to recharge when aquafer recharge potential is at its highest.

During the study, California state recovered from the multi-year drought and interest has increased for the assessment of preparedness of handling of extreme flooding events. Additionally, efforts to respond and implement the Sustainable Groundwater Management Act have rapidly evolved to meeting 2018 deadlines.

A next step for others interested in this study would include the application of water rights to assess feasibility in further detail. Additionally, stakeholder outreach indicated that there was more interest in flooding of land adjacent to fields or in using existing unlined canals to create a supply of groundwater rather than the flooding of specialty crops fields; noting the risk and continued research on the impacts on crops.

Additional Information (Please respond to all bulleted items)

Visit the Storymap produced for this project:

https://sacog.maps.arcgis.com/apps/Cascade/index.html?appid=10ecb2a91eb94a32a35f37e7f4742dd1

Project website:
https://www.sacog.org/post/sustainable-water-management-strategies-specialty-crop-expansion-sacramento-valley

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 43	**Project Title:** Mineral Nutrient Requirements of Table Grape Cultivars in the San Joaquin Valley and Effects of N Rates on Fruit Quality	
Grant Recipient: California Table Grape Commission	**Grant Agreement No.:** SCB15043	**Date Submitted:** December 2018
Recipient Contact: Karen Hanson	**Telephone:** (559) 447-8450	**Email:** karen@grapesfromcalifornia.com

Project Summary

The purpose of the project was to determine the amount of nitrogen (N) table grapes need in order to develop N and potassium (K) budgets for the major table grape cultivars. Optimizing N application is essential for sustainability of farms and the environment. Too much N can result in excessive canopy growth, which can impede color development and negatively influence next year's crop. Applying less N than the crop requires will limit the production.

Research quantified the approximate amounts of N and K needed for optimum vine growth, production, and fruit quality for major, newer table grape varieties. Table grape growers are currently using guidelines developed in the 1990s for Thompson Seedless table grapes, a variety that is now grown only on 3,777 out of 85,166 bearing table grape acres in California. The newer varieties are more productive than Thompson Seedless, and new vineyards are commonly drip-irrigated and supported with larger trellises that differ from the typical table grape trellis used in the past; both factors can increase total biomass production by the vines and may increase the demand for nitrogen and potassium. The newer varieties ripen from June until December. Proper timing and amount of N fertilizer applications are critical for optimizing N uptake, yield and crop quality, while minimizing leaching below the root zone, which is a concern in the San Joaquin Valley.

The goal of this research was to determine N needs for the Crimson Seedless, Flame Seedless, Scarlet Royal and Autumn King varieties, including the optimum timing and rates for maximum N uptake and fertilizer use efficiency, in order to maximize yield and crop quality. In addition, N and K budgets for the aforementioned and additional two white table grape varieties, Sheegene-21 and Princess, were developed in this research.

Approximately 99 percent of the United States (U.S.) table grapes are produced in California; 95 percent are produced in the southern San Joaquin Valley counties of Kern, Tulare, Fresno and Madera. The proposed research would quantify the approximate amounts of N and K needed for optimum vine growth, production and fruit quality for major, newer table grape varieties, which are currently using outdated guidelines with declining table grape acreage.

It is important to provide the industry with more current information for the more widely grown varieties. In the 2017-2018 season, the six varieties that are the focus of this research represented 49 percent of the total crop volume of 109.1 million box units.

Proper timing and amount of N fertilizer applications are critical for optimizing N uptake, yield, and crop quality while minimizing leaching below the root zone, which is a concern in the San Joaquin Valley. The California table grape industry identified this research as a high priority, and initiated proof of concept

grapevine nutrient research in May of 2014 with its own funds, and the industry has continued to provide funding and in-kind support for this research.

This research addressed the program priority of assisting specialty crop growers and others in the distribution chain to develop and implement Good Agricultural Practices and Good Handling Practices. Determining optimum N fertilizer application doses and timings to maximize nutrient uptake in vines and improve fertilizer use efficiency. Developing N and K budgets for newer and widely grown table grape varieties that ripen from July to November will determine how much N each variety needs for optimum growth and production of quality fruit. Growers will learn how to best manage their fertilization program to optimize yield and quality and minimize leaching of N (Good Agricultural Practices). This project enhances the sustainability and competitiveness of the California table grape industry by providing information to growers on how to optimize fertilizer applications, while preserving the environment.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Experiments were conducted to determine how different N applications affect yield and fruit quality of Autumn King, Flame Seedless, Scarlet Royal and Crimson Seedless table grapes (*Vitis vinifera* L.) located in San Joaquin Valley.

All vineyards employed large open gable trellises, which are commonly used in newer vineyards, and drip irrigated according to the cooperator's irrigation schedule. Irrigation water in all vineyards was analyzed for nitrate content every two to three weeks during the growing season. Water meters were installed in each vineyard (a minimum of three per vineyard) and the amount of applied water was recorded. Applied water amounts were compared with estimates of vineyard evapotranspiration (ET_c). Vine water status was monitored periodically with a pressure chamber. Other vineyard operations, with the exception of fertilizer applications, were performed by the grower's personnel at each vineyard site. Multiple soil samples were collected and analyzed for soil texture, moisture, organic matter, and nitrate contents.

In differential N experiments, various N amounts were applied in either of two split application treatments; 1) 'slug', in which half the total amount of N applied was delivered one month after budbreak and the second half after berry set, or 2) more numerous 'spoon feed' applications in which the total amount of N applied was delivered in up to 10 equal amounts, each applied every two weeks over a 20-week period. The doses were 1N (to replace the amount of N removed by fruit), 2.5N (2.5 times the amount of N removed by fruit), and 0N (control).

The biomass, N and K content of shoots, petioles, leaves, and clusters for the Autumn King, Crimson Seedless, Flame Seedless, Princess, Scarlet Royal, and Sheegene-21 grapevines were collected from vines at bloom, veraison, and harvest.

In all vineyards, leaf and stem biomass was estimated at anthesis (bloom), veraison, and harvest in order to develop the N and K budgets. Leaf and stem dry biomass was estimated by taking five individual shoot samples randomly collected within a treatment plot, removing leaves from the stems, and drying both tissues separately. On all three sample dates, the calculated dry biomass of an individual stem (or leaves on those stems) within a treatment plot was determined and that value multiplied by the total number of shoots per vine

(the numbers of shoots per vine within a treatment plot was determined by counting the shoots early in the growing season). Average, individual cluster dry biomass was determined at bloom and veraison by removing clusters from the five shoots chosen above from data vines and determining their average dry weights. Table grape vineyards are usually harvested several times each season. At each harvest, all clusters were counted and the total cumulative number was taken as the number of clusters at bloom and veraison. Therefore, mean cluster dry weight per treatment plot at bloom and veraison was multiplied by the total number of clusters at harvest to estimate fruit dry biomass at those times. All clusters (including cull fruit) were also weighed on each harvest date and summed to determine total fruit biomass. At one harvest date for each variety, the fruit were sub-sampled, fresh sample weight determined, and the sampled fruit were then dried to help estimate total fruit dry biomass at harvest.

All vine organs collected in the field were dried in a forced air oven at 70°C until no further decrease in weight, and dry weights were recorded. Data were analyzed by analysis of variance and means separated as appropriate using Duncan's multiple range test. Regression analyses were used to compare N and K concentrations in the leaves, stems and clusters with N and K values in the petioles.

The amount of N per vine was calculated as the product of the N concentration (g TN 100 g^{-1} dry weight) of leaves (TN_{lh}), stems (TN_{sh}) and clusters (TN_{fh}) and the estimated dry biomass of leaves and stems and actual dry biomass of clusters (Tb_{fh}) per vine. Estimated stem biomass (Tb_{sh}) on each date was calculated by multiplying average stem dry weight by the number of shoots per vine. Leaf and cluster biomass was estimated. Total N per vine on each harvest date (phenological stage) was calculated as:

$$TN = (Tb_{lh} \times TN_{lh} + Tb_{sh} \times TN_{sh} + Tb_{fh} \times TN_{fh}) \times 0.01$$

In experiments where vines were subjected to differential N fertilization treatments, mineral nutrient and biomass data were collected, along with berry quality measurements (weight, firmness, color, soluble solids and titratable acidity), and commercial pack-out data. Additionally, professionally packed fruit were held in cold storage for one and a half months, and post-harvest quality (rot, rachis browning, and firmness) was evaluated.

At the end of the season leaves were collected as they fell from the vine (netting was placed under one individual vine per treatment plot to capture leaves as they fell and prevent cross-contamination) to provide an estimate of N in the fallen leaves. The amount of N within leaves after harvest and remobilized to the permanent structure of the vine were quantified as the difference in leaf N after leaf fall and leaf N in the canopy during September. Cane biomass was measured at pruning.

The fertilizer recovery efficiency (RE_N) of N is defined as the fraction of fertilizer N taken up by the vines in relation to the amount of N applied (N_{ap}) was calculated as follows:

$$RE_N = (N_{fs} - N_{nfs})/(N_{ap}) \times 100$$

where N_{fs} represents the amount of N found in the fertilized sample, N_{nfs} is the amount of N in the non-fertilized treatment and N_{ap} is the amount of N applied per vine.

The estimated N from fertilizer (ENF) is the absolute amount of N in the organs (or vine) that came from the applied fertilizer. The percent N derived from fertilizer (%NDF) is the relative amount of N present in the organs (or vine) that came from the applied fertilizer ($N_{fs} - N_{nfs}$) in relation to the total amount of N ($N_{tn\,fs}$) in the sample. Thus, ENF and %NDF were calculated as follows:

$$ENF = N_{fs} - N_{nfs}$$

$$\%NDF = (N_{fs} - N_{nfs})/N_{tn\,fs}) \times 100$$

The overall scope of the project did not benefit commodities other than specialty crops. The research is specific to six table grape varieties: Crimson Seedless, Flame Seedless, Scarlet Royal, Sheegene-21, Princess and Autumn King, as cultivated in the San Joaquin Valley. The project's research (sampling and analysis) is highly specific to table grape vineyards.

The commission worked in partnership with University of California researchers, who were responsible for the day-to-day project activities and worked in cohort with the commission scientists to conduct fruit quality evaluations. California table grape growers provided access to vineyards for use in the data collection. The commission surveyed table grape growers to identify prospective vineyards for the fertilization experiments, and then served as a liaison as needed.

The commission's Grapevine Nutrient Advisory Committee and the Viticulture Research Committee provided cooperation, oversight, expertise, and direction to the lead researchers and commission staff. This occurred when the lead researchers presented the research, during the dissemination of notes and materials, and via staff communication with committee members and researchers.

Goals and Outcomes Achieved

Goal 1 of the project was to evaluate the effect of N rate application timing on table grape yield and fruit quality. The table grape yield and quality was evaluated as a function of applied N. Project staff used two benchmarks in order to evaluate the effect of 0N or 2.5N applied and to measure benefits of "spoon-feeding" method. The first benchmark was to use the quality and yield data of table grapes after N application in order to replace the amount of N removed in the fruit from each vineyard the previous year (1N treatment). The second benchmark was to apply the amount of N in two slug applications. The target to identify application that results in highest yield, and fruit quality was met.

There was no one particular treatment that always resulted in the highest yield and quality. The best fertilizer treatment will depend on condition and N status of the vines, the crop history, and environmental influences including the amount of N in irrigation water. For example, in some trial sites, N fertilization either did not affect fruitfulness (the number of clusters per vine, as counted in the spring), or increased it modestly, with no effects on yield. In these vineyards, N fertilization likely had little effect because the N in irrigation water, together with the N already present in non-fertilized vines and soil, was sufficient to sustain fruitfulness over the course of the studies (three seasons). In such vineyards, N fertilization often had little effect on fruit quality, though the highest levels of N fertilization sometimes delayed ripening, which could be undesirable or desirable depending on market conditions and marketing strategy for a given variety.

However, the results described above are in marked contrast to those observed in a vineyard with low N content in irrigation water and having vines with low levels of N at the beginning of the study. In a low N vineyard, N fertilization substantially increased N content of the various vine organs, biomass produced per vine, the number of clusters per vine, fruit biomass at harvest, and certain fruit quality attributes (berry size and color). In this vineyard, the highest level of N fertilization was needed to maximize vine growth, and fruit productivity and quality.

The RE_N was relatively high in most vineyards, especially for vines receiving the replacement amount of N (1N, the amount of N estimated to be in the fruit removed from the vineyard in fruit harvested the previous season), and project staff believe in most vineyards annual replacement of the amount of N removed in harvested fruit is a good practice as recovery efficiency is high and the N applied will help prevent or slow the onset of N deficiency. In contrast, in N deficient vineyards, replacing the N removed in harvested fruit is insufficient to rapidly restore the vines to sufficiency as evidenced by the fact that vines receiving 2.5N for three consecutive years still have marginal petiole N levels (though much higher than non-fertilized vines in the same vineyard) and total N per vine is still half of that of Flame Seedless vines in other vineyards (due to lower N concentration in vine tissues and smaller vine size). Yields are also lower in this vineyard, even for vines receiving the most N.

Goal 2 of the project was to quantify the uptake of N and K in the leaves, stems and clusters of Flame Seedless, Scarlet Royal, Crimson Seedless grapevines as a function of three N fertilizer treatments and their timing of application (develop N and K budgets for these cultivars). Different amounts of N and K were measured as a function of applied treatments. Vines not fertilized with N served as the control. The target to determine uptake of N and K in the leaves, stems, and clusters was met.

The N amassed in leaves, stems, and clusters varied depending on the variety, treatment, and time of year when measurements were made. By harvest, vines in most vineyards amassed 100 to 150 g N per vine, though Flame Seedless vines in the low N vineyard only amassed 40 to 70 g N per vine by harvest. In Crimson Seedless and Scarlet Royal, approximately 33 to 38 percent of the N was in fruit at harvest time, with the remainder in stems and leaves. In contrast, in the N-deficient Flame Seedless vineyard, only about 17 percent of the N was in the fruit, 55 percent was in leaves, and the remainder in stems. The relatively low partitioning of N to fruit in Flame Seedless was partly due to much lower concentration of N in the fruit and to less fruit compared to the Crimson Seedless or Scarlet Royal. Therefore, vines take up more N if supplied with more N, but the uptake is not necessarily proportional to the amount applied.

Vines were not subjected to any K fertilizer treatments, but project staff found that K uptake was affected by N treatments and differed according to sampling time and organ sampled. In general, increased N fertilization reduced K content. At harvest, K content in leaves ranged from 0.88 to 1.09 percent on a dry weight basis. In stems K was about 0.95 percent on a dry weight basis, regardless of N treatment. In clusters, K ranged from 1.18 to 1.05 percent depending on N fertilizer treatment.

The N uptake increases with the amount of N applied, but not necessarily proportionally. In most cases replacing the amount of N removed in harvested fruit appeared to be the “best” treatment, sustaining yield and quality and having a high RE_N. However, in N deficient vineyards, providing the “replacement” value of N was insufficient to restore N values; 2.5N was a better commercial treatment in that case. When high levels of

N are needed to recover from N deficiency, splitting the N applications into many small applications resulted in better RE_N compared to fewer applications.

Goal 3 of the project was to determine the RE_N of the six table grape cultivars using the N difference method. Project staff took the total uptake of N by vines in the N maintenance fertilizer rate and the 2.5N rate treatments and compared their timing of application to the 0N fertilizer control treatment. The target to identify the treatment that results in most N uptake was met.

The RE_N varied according to variety but was usually most strongly affected by the amount of N applied and by the number of split applications. In general, the replacement N treatment had higher RE_N than the 2.5N treatment, and recovery efficiency was increased by applying N over the course of ten applications compared to two applications, especially when 2.5N applications were made. For Flame Seedless project staff observed RE_N from 30 to 100 percent; in Crimson Seedless RE_N ranged from 20 to 34 percent; and in Scarlet Royal RE_N ranged from 32 to 75 percent. In each case the lower RE_N was for N applied in two applications (regardless of amount of N applied). Project staff are not sure why RE_N in Crimson Seedless was notably lower than in the other varieties. It may have to do with irrigation strategy in that vineyard, as the vines were sometimes flood irrigated, but it could also be due to differences in rootstock, as all of the trial vineyards were on 1103P rootstock except for the Crimson Seedless, which was own-rooted. Many rootstocks, including 1103P, can increase N uptake. The 1103P rootstock is also more resistant to nematodes, which might further improve root ability to take up N from the soil.

The most N uptake was usually for vines given 2.5N, though that treatment was usually the least efficient with respect to RE_N.

Goal 4 of the project was to compare the percent and total N and K uptake in leaves, stems and clusters of the above three mentioned cultivars as well as the N amounts and timings of application with other means to determine vine nutritional status. The target to compare and identify best method was met.

Nutrient contents in various organs were generally correlated with each other, though the strength of the correlation varied widely depending on growth stage and specific organs being compared. Petiole nitrate content was sensitive to vine N status and was easy to measure. Project staff recommend replacing the N removed by harvest in N-sufficient vineyards but measuring N in fruit is less convenient than measuring it in petioles. However, fruit from N-sufficient vineyards typically contains approximately two to three pounds of N per ton of fruit. Therefore, if bloom-time petiole N values indicate sufficiency (>200 ppm), and the vines have a normal appearance (leaf color, fruit productivity, and growth are normal) replacing the N removed by harvest may be sufficient, at least for several years. Otherwise additional N may be required (at least 2.5N).

The K uptake was affected by N treatments and differed according to sampling time and organ sampled. In general, increased N fertilization reduced K content. At harvest, K content in leaves ranged from 0.88 to 1.09 percent on a dry weight basis. In stems K was about 0.95 percent on a dry weight basis, regardless of N treatment. In clusters, K ranged from 1.18 to 1.05 percent depending on N fertilizer treatment.

The research determined N uptake in several major red and green table grape varieties grown on modern gable trellis as function of applied N and evaluated effects of N rates on yield and grape quality. Prior to this research, there was no data available on these viticulture practices.

Experiments were conducted in commercial table grape vineyards to determine optimum amount and delivery of N. The experiments varied the amounts of applied N fertilizer, and the number of split fertilizer applications served to determine effects on growth, yield and fruit quality for Autumn King, Crimson Seedless, Flame Seedless, and Scarlet Royal varieties. The RE_N was estimated.

Different methods for assessing vine N status were compared. The biomass, N and K content of shoots, petioles, leaves, and clusters of Autumn King, Crimson Seedless, Flame Seedless, Princess, Scarlet Royal, and Sheegene-21 grapevines were collected from vines at bloom, veraison, and harvest. The N budgets were developed for the collected data.

Optimizing N application is essential for sustainability of farms and the environment. Too much N can result in excessive canopy growth, which can impede color development and negatively influence next year's crop. Applying less N than the crop requires will limit the production. The results from this research will provide table grape growers with the approximate amounts of N and K that different cultivars need for optimum vine growth and fruit quality.

The project's research and results were disseminated at the following events:

- Grapevine Nutrient Advisory Committee, February 4, 2016
- Grapevine Nutrient Advisor Committee, February 2, 2017
- Grapevine Nutrient Advisory Committee, February 1, 2018
  - The advisory committee met to review the activities and results of work conducted each year. The research project leaders presented reports and a PowerPoint summarizing the activities and results. The meeting notes and materials were sent to the members of the viticulture research committee.
- Viticulture Research Committee, April 1, 2016
- Viticulture Research Committee, March 30, 2017
- Viticulture Research Committee, March 23, 2018
  - The project leaders presented the research and results to the commission viticulture research committee.
- 2017 California Table Grape Seminar in Visalia, California sponsored by the California Table Grape Commission. Approximately two hundred table grape growers and industry members attended the seminar.
- FREP/WPHA Nutrient Management Conference in Modesto, California, on November 2, 2017.
- "Nitrogen Management in Table Grapes" was presented during the Southern San Joaquin Valley Grape Symposium on January 18, 2018 in Bakersfield, California. This event was organized by Kern County University of California Cooperative Extension, and Consolidated Central Valley Table Grape Pest and Disease Control District.

Beneficiaries

The groups and operations that benefited from this research include California table grape growers, the communities where the growers live and work, and the related economic segments.

The primary beneficiaries of this research are California table grape growers, who produced 109.1 million boxes in 2017 with a crop value of $1.81 billion. This project will enhance the sustainability and

competitiveness of the California table grape industry by providing information to growers on how to optimize fertilizer applications, while preserving the environment.

The secondary beneficiaries of this research are those who live in the California table grape growing areas. The benefits are two-fold: improved economics tied to the competitiveness of table grapes as a California specialty crops, and the positive environmental impact of the optimized fertilizer applications.

Developing Good Agricultural Practices will have a broad impact on all state residents through benefit to the environment.

The research will benefit the 450 table grape growing operations in California, the majority of which are family-owned and operated. The table grape operation employees and local economic sectors benefit as well.

The United States Department of Agriculture – Economic Research Services showed that in 2014, each dollar of agricultural exports stimulated another $1.27 in business activity. In 2017, approximately 35.8 percent of the California table grape crop was exported, which would have generated an additional $986,471,230 in business activity for these exports.

Lessons Learned

Initiating the preliminary research with the commission funds, prior to applying for the Specialty Crop Block Grant Program grant, enabled fine-tuning of the experimental design, methodology, and logistics prior to receiving the grant, which resulted in prompt and smooth execution of the proposed work.

All goals and outcomes for the grant project were achieved.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 44	**Project Title:** Combined Denitrification and Blackberry Production in Woodchip Bioreactor	
Grant Recipient: Coastal San Luis Resource Conservation District	**Grant Agreement No.:** SCB15044	**Date Submitted:** December 2018
Recipient Contact: Jacki Crabb	**Telephone:** (805) 772-4391	**Email:** jcrabb@coastalrcd.org

Project Summary

Blackberries have become a valuable specialty crop on California's Central Coast, which has an ideal climate for blackberry production. The Central Coast Regional Water Quality Control Board (RWQCB) implemented discharge regulations, known as the Ag Order, intended to reduce nitrate pollution from irrigated lands. This project was proposed to conduct research on the feasibility of blackberry production on a wood-chip substrate. The specific issue to be addressed was the economic and agronomic feasibility of blackberry production on a continuously irrigated wood chip substrate. Woodchip bioreactors have been successfully used as a best management practice (BMP) for denitrification of agricultural runoff. This project was intended to assess the feasibility of using woodchip bioreactors to produce blackberries. Using woodchip bioreactors for blackberry production has the potential to enhance the competitiveness of the blackberry industry by reducing fertilizer costs, reducing irrigation costs, reducing irrigation water management, and helping blackberry growers comply with environmental regulations. Nitrate that would otherwise pollute the water supply could be made available to the blackberry plants, stimulating growth. The continuously irrigated woodchip substrate would provide maximum water availability while simultaneously reducing evaporation. The use of wood chips may also make it possible to grow blackberries in areas where the soil would otherwise not be suitable.

The results of this project were presented to Central Coast growers with an economically viable practice to produce blackberries while reducing nitrate pollution and, in turn, complying with the Ag Order. By demonstrating that blackberries can be a viable crop to be planted on top of bioreactors on the Central Coast, blackberry growers and the industry can directly benefit.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The project team underwent a number of tasks to meet the goals and objectives of this project:

Task 1: On October 20, 2016, 100 PrimeArk 45 blackberry plants were planted. The survival rate of the plants was 100 percent throughout the duration of the project. Fruit samples from the bioreactor and three control plantations were compared for the following: yield, weight, percent soluble solids, sugar, and general nutrients. A Hydrolab MS5 minisonde with nitrate sensor was deployed in the bioreactor beginning in March 2017. Over the course of four months, nitrate level readings from the sensor were erratic and did not track with the nitrate analysis results from weekly nitrate samples submitted for lab analysis. The sensor was sent in to the manufacturer twice for troubleshooting and subsequent replacement. The nitrate sensor did not yield accurate nitrate readings within the duration of the project. Instead, the project team relied on samples sent in weekly to a laboratory for testing.

Task 2: Operation and maintenance of the bioreactor and plantings was ongoing during the term of the grant. Cane pruning, photo monitoring (Attachment 1), and fine-tuning of the valve system occurred during weekly field visits. The average effluent concentration was 5.3 ppm of nitrates. The average removal efficiency of nitrates in the bioreactor system was 75 percent.

Task 3: Water quality was monitored weekly from April 2017 to June 2018 (Attachment 2). Water quality trends were generally consistent with seasonal fluctuations (Figure 1). Nitrate levels were logged to determine de-nitrification trends (Attachment 3) Denitrification trends also fluctuated seasonally, though effluent levels remained below 10 ppm (Figure 2).

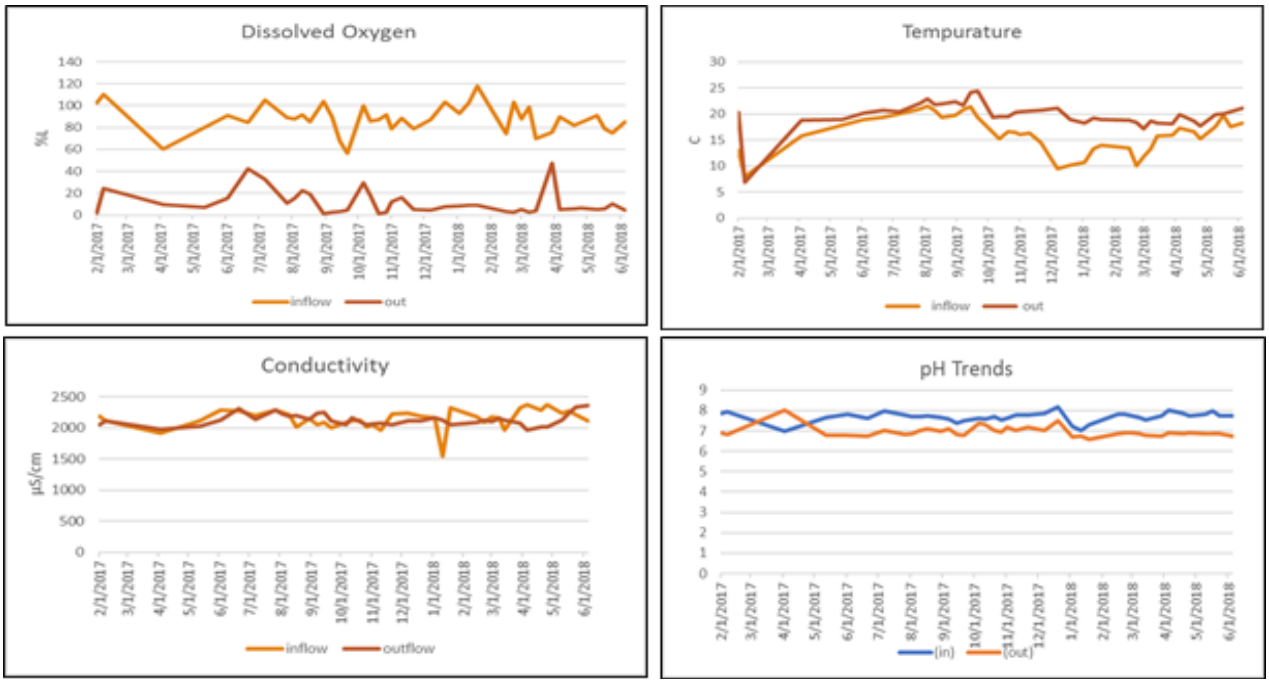

Figure 1. Water quality trends

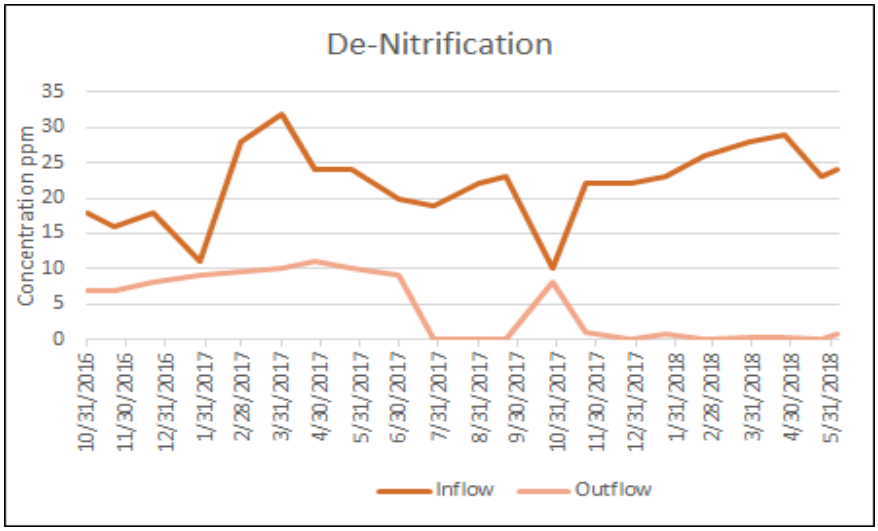

Figure 2. Denitrification trends

Task 4: Fruit was collected and analyzed from the bioreactor and three control plantations between July 2017 and December 2017. Control plantations were chosen based on geographic proximity, comparable soil type, and similar growing conditions to the bioreactor plantation. Control plantations were within 20 miles of the bioreactor plantation, planted with the same variety of berry, and farmed using organic practices inside hoop houses (Figure 3).

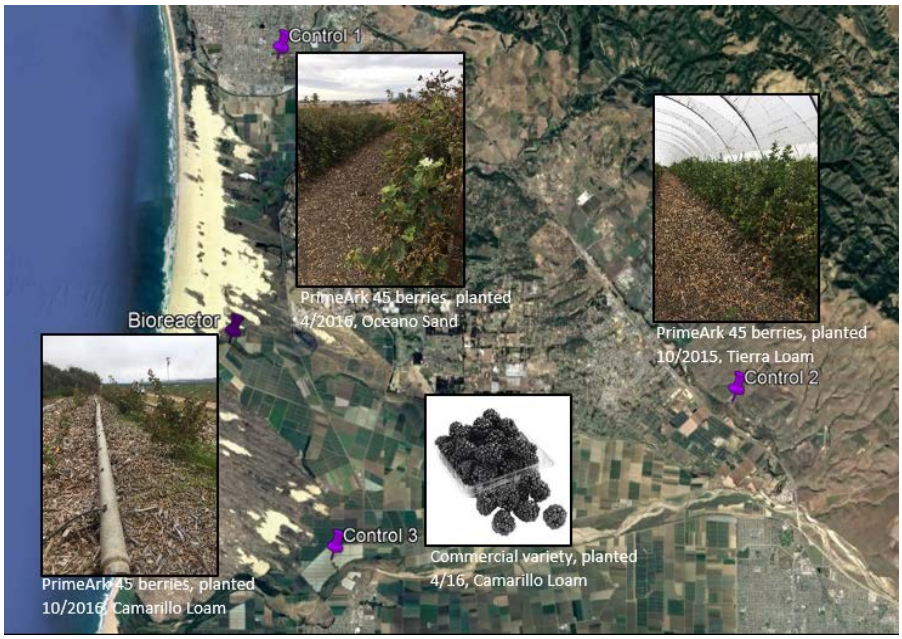

Figure 3. Plantation locations

Plant vigor was measured by flower set and cane development and were recorded weekly (Attachment 4). Laboratory results indicated that samples from the bioreactor had lower yield, and fruit mass compared to samples from the control plantations (Figure 4). This was due to predation from birds and deer, and a lack of wind protection. Nitrate levels in samples from the bioreactor were lower than samples from the control plantation one, though it was known that groundwater levels of nitrates were high at this plantation. Nitrate levels in samples from the bioreactor were slightly elevated compared to samples from control plantation two and three, though do not pose a health risk.

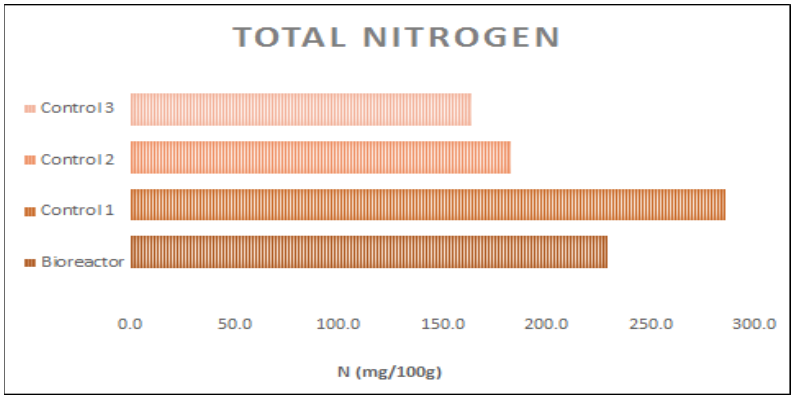

Figure 4. Comparison of nitrate levels in fruit samples

Task 5: Two on-site demonstrations were held. On October 4th, 2017, a field demonstration of the bioreactor system was hosted for the State Water Resource Control Board Nonpoint Source and Grant Program group. On May 25th, 2017, a demonstration of the bioreactor system was given to the RWQCB Total Maximum Daily Load (TMDL) Division. Over 65 people attended the demonstrations. Additionally, three presentations were given during the term of the project. The first presentation was during a Rangeland Management workshop, hosted by the Coastal San Luis Resource Conservation District (CSLRCD) and California Polytechnic State University (Cal Poly) on December 15, 2016 and focused on the technology of the bioreactor system. Next, on March 9, 2017, the bioreactor system was highlighted in a presentation to the RWQCB Technical Advisory Committee. Lastly, on June 8, 2018, the final results of the project were presented to the Agricultural Systems Engineering group at Cal Poly. A summary of the presentations and field demonstrations given is provided in Figure 5. A technology fact sheet was distributed among participants of each demonstration and presentation (Attachment 5).

Activity	**Number of Participants**	**Date**
Presentation at the Rangeland Management Workshop	40	12/15/2016
Field Demonstration for RWQCB TMDL division	30	5/25/2017
Field Demonstration for SWRCB Nonpoint Source and Grant Program group	35	10/04/2017
Presentation to RWQCB Technical Advisory Committee	35	3/9/2018
Presentation for Agricultural Systems engineering Group	30	6/08/2018
Article in CSLRCD Quarterly Newsletter	175	6/30/2018
TOTAL	**345**	

Figure 5. Total number of attendees

The overall scope of the project did not benefit commodities other than specialty crops. All project expenditures were tracked to ensure that funds were used to solely enhance the competitiveness of specialty crops.

University of California Cooperative Extension (UCCE) crop advisors provided the blackberry plants and consulted on the care and maintenance of the plants for optimal yields plant vigor. UCCE also identified additional berry growers in the region, whose blackberry plants were used as comparison specimens. Mills Farms, leasing land from the California Department of Parks and Recreation, where the bioreactor was located, provided access, labor, and materials to the project, and agreed to utilize and maintain the project after the duration of the grant.

The California Department of Parks and Recreation also committed to support the maintenance and promotion of this project after the grant term had expired.

The RWQCB included the project in a tour of regional BMP projects. Based on the success of this project, CSLRCD staff have been invited to participate in the RWQCB Technical Advisory Committee for Bioreactors.

Goals and Outcomes Achieved

Goal One: The primary goal was to demonstrate the feasibility of producing commercial blackberries on the bioreactor. To achieve this goal, fruit samples from the bioreactor and three control plantations were compared for the following: yield, weight, percent soluble solids, sugar, and general nutrients.

Due to varying ages of plants and growing conditions, plant vigor data were only collected from plants at the bioreactor. Plants in the three control plantations were either more mature, and so were more developed, or planted in a hoophouse, and so were more vigorous. The plant vigor data collected from the bioreactor will be used in future comparative studies. Plant vigor was recorded, and a comparative fruit analysis was conducted (Attachment 4).

Targets established for Goal One included a comparison of blackberry properties grown in the treatment system to blackberry properties grown on farms without a bioreactor system. The properties compared were: fruit yield (pounds per acre), average fruit mass (grams), sugar content (Brix), sweetness (percent soluble solids), and cane vigor (number and length of cane). Samples were analyzed for the above properties as well as nutritional content in the lab. Nutritional content analysis included: percent moisture total nitrogen, phosphorus, potassium, calcium, sodium, and iron. Nutritional analysis indicated that concentrations of potassium, boron and copper, as well as percent moisture in samples collected from the bioreactor were comparable to samples collected in the control plantations. Samples collected from the bioreactor contained higher concentrations of phosphorus, calcium, sodium and iron than samples collected in the control plantations, and lower concentrations of manganese (Attachment 4).

Results for yield, weight, sugar, and solids indicated that samples collected from the bioreactor were lower than samples collected at the three control plantations. Control plantations varied from growing conditions at the bioreactor plantation: plants in control plantation one were planted the previous year, plants in control plantation two were grown under a hoop house. Differences in growing conditions resulted in lower yields, weights, and sugar content from the samples collected from the bioreactor plantation. Control samples appeared to benefit from hoop house conditions as the plants were able to grow for a longer time on the plant and were not lost to predation, resulting in higher weights, sugars and yields.

Plant vigor data were collected from plants on the bioreactor. Plant vigor data were not collected from the control plantations due to the variations in age, pruning methods, and cover. UCCE crop advisors advised that vigor and fruit set of plant in the bioreactor system demonstrated the feasibility of the production of blackberries on a bioreactor.

Goal Two: The secondary goal of this project was to demonstrate nitrate reduction. During the term of the project, 74 pounds of nitrates were removed from the Oso Flaco watershed by the denitrifying bioreactor. Load reduction was determined by weekly calculations of nitrate concentrations entering and leaving the bioreactor system, along with flow measurements (Figure 6). The nitrate levels in effluent exiting the bioreactor were consistently below drinking water standard levels of 10 ppm of nitrates.

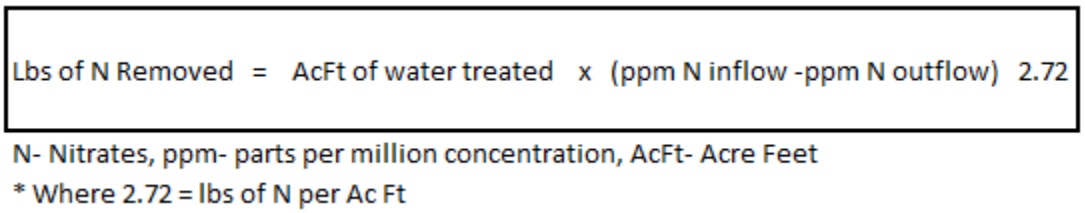

Figure 6. Nitrate reduction calculation.

Goal Two set a target of reducing nitrate concentrations in effluent water to 10 ppm. The concentration of nitrates exceeded 10 ppm just two times during the project term.

Goal Three: The third goal of the project was to increase grower knowledge of the benefits of using bioreactors for blackberry production. The objectives of Goal Three were to conduct one field demonstration and two presentations, publish project findings in a fact sheet and on CSLRCD website, as well as prepare a technical memo for publication. Two field demonstrations were held, and three presentations were given, reaching over 150 individuals. A technology fact sheet was developed and circulated to growers, water quality specialists, resource agencies and students. The project team began the process of developing a technical memo documenting the findings of the project for publication. Project findings were also published on CSLRCD website, coastalrcd.org, and included in the quarterly newsletter.

Goal One: Comparative analysis of control samples and the samples collected from the bioreactor plantation indicated that control samples had higher yields, weights, and sugar content, while a nutritional analysis shows the nutrient content of all samples to be relatively similar (Attachment 4).

Goal Two: The nitrate reduction log tracked the volume of water treated and mass of nitrates removed over the course of the project term (Attachment 3). Concentrations of nitrates in the effluent were consistently lower than 10 ppm, a target both established for this project as well as the for the maximum concentration for drinking water determined by regulatory standards.

Goal Three: Two field demonstrations and three presentations were made during the term of this project, exceeding the target of one demonstration and two presentations.

The reduction of nitrates from the Oso Flaco watershed was successful and quantifiable by the end of the project. Over 74 pounds of nitrates were removed and 750,100 gallons of water were treated by the bioreactor during the term of this project (Attachment 3). Concentrations of nitrates were reduced by an efficiency of 75 percent and were consistently below drinking water standards of 10 ppm. Reduction efficiency was calculated based on the average reduced concentration (ppm) divided by the average inflow concentration (ppm).

Beneficiaries

Beneficiaries of the accomplishments of this project included the following groups:

Specialty crop farmers, growers and land managers that either participated in one of the demonstrations or presentations, received the project fact sheet, or read the CSLRCD quarterly newsletter. This group received information and resources about bioreactors as an on-farm tool.

Regulatory staff from the SWRCB and RWQCB, United States Environmental Protection Agency staff, and other resource agency representatives whom attended the two field demonstrations and presentations. This group saw how this effective technology can be used to attain the goals of resource agencies.

Agricultural engineering students whom participated in the presentation in June 2018. This group was presented with the background and technical details of this tool for future implementation and promotion.

In total, the project team was able to reach 345 people through presentations, field demonstrations, and publication in the CSLRCD quarterly newsletter.

Lessons Learned

Project Scale: The size of this project was appropriately scaled to effectively collect and analyze all data, and to demonstrate the functionality of the bioreactor system to groups ranging from 10 to 40 people. The scale showed local growers how a bioreactor system could fit on their farmland, while also demonstrating an effective treatment level at which resource agency representatives may hold an interest.

Outreach: Various partners collaborated on all aspects of the project from initial development to future phases outside of the scope of this work. A high level of collaboration enhanced the quality and content of project results. For example, SWRCB involvement provided needed insight to the forthcoming Ag Order and how implementing bioreactor systems could assist growers with meeting the upcoming State requirements. UCCE and Cal Poly partners assisted with expanding the scope of work as well as assistance in understanding project benefits. Lastly, involving the California Department of Parks and Recreation enabled a stronger partnership and resulted in future and maintained collaboration.

Data Collection: When initially conceived, the project included collection of a specific set of criteria from control plantations with similar environmental conditions to the bioreactor plantation. However, the three control plantations varied slightly from the bioreactor system, in age of plants, growing conditions or pruning method. The variation in conditions made collecting plant vigor data difficult. Consistent conditions among control plantations would have resulted in more meaningful conclusions.

The nitrate sensor specified and installed for the automation and optimization of denitrification in the bioreactor was not ideal. The sensor should have controlled the time that water remained in the bioreactor to optimize the volume of water treated. The sensor utilized was unable to complete this task. Numerous attempts installing, calibrating, and troubleshooting the sensor failed to return accurate data on the denitrification trends in the bioreactor. Ultimately, manual adjustments to the system resulted in an optimized volume of water treated and nitrates removed by the system. Efforts will continue to retrieve accurate data from the nitrate sensor.

Results from nutrient analysis of all samples collected indicated that sodium levels in the samples collected from the bioreactor were considerably higher than the samples collected from the three control plantations. It is uncertain why the bioreactor sample concentrations were high, considering the relatively similar levels of other nutrients across all samples. This finding sparked the need for additional research to be conducted and will therefore be assessed in future studies on this bioreactor system.

Targets established in Goal One identified criteria for fruit quality analysis and plant vigor monitoring. The criteria were difficult to document in the control sites because of climatic differences, plantation age, and pruning methods from the bioreactor system. To produce more meaningful results in future studies, the control sites should not vary in biotic or abiotic conditions.

Additional Information

See attachments 1-5.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 45	**Project Title:** Development of Lettuce Cultivars with Increased Water and Nitrogen Uptake	
Grant Recipient: Cal Poly Pomona Foundation	**Grant Agreement No.:** SCB 15045	**Date Submitted:** December 2018
Recipient Contact: David Still	**Telephone:** (909) 869-2138	**Email:** dwstill@cpp.edu

Project Summary

Lettuce is produced on approximately 233,000 acres in California, and with an annual farm gate value of approximately 2 – 2.4 billion dollars, it is the most valuable vegetable crop in the state. Lettuce crops require a dependable supply of high quality water and high nitrogen (N) fertilizer inputs. Global warming has changed the climate and weather patterns in California and this has repercussions to agriculture. A historic drought, wide oscillations in winter precipitation and long-term water deficits contribute to an uncertainty regarding water availability for California crops. In addition to water, N fertilizers are a concern to California agriculture. Nitrogen fertilizers not taken up from the soil by the lettuce crop can be lost to leaching of nitrate (NO_3), contributing to groundwater pollution and unsafe drinking water for communities. Additionally, N fertilizers that remain in the soil can volatilize and release nitrous oxide (N_20) into the atmosphere. Nitrous oxide is a long-lived greenhouse gas with 300 times more global warming potential than carbon dioxide. Nitrogen-based fertilizers are by far the major anthropogenic source of this greenhouse gas. Lettuce leaves grow rapidly and require high amounts of N fertilizer to support this growth and develop proper shape, size and density. To sustain the economic feasibility of the lettuce industry and lower the environmental impact of growing this crop, cultivars with increased N and water use efficiency (NUE, WUE, respectively) are needed. The objective of this work was to develop breeding lines and genetic tools for breeders to use as they develop cultivars with increased WUE and NUE.

The consensus of climate models is that global warming will result in warmer storms with more precipitation falling as rain leading to reduced winter snowpack, more frequent and longer droughts, and oscillations between wet and dry winters. Competing demands for California's water supply will only increase and less water may be available for agriculture. California has experienced a sustained long-term warming trend, and 2017 was the warmest season on record, breaking the previous record set in 2016. Warmer temperatures increase evapotranspiration, causing crops to require more water. Nitrogen fertilizers are a relatively inexpensive cost of the farming operation and plant growth responds proportionate to amount of N available. The ability to grow lettuce crops with less N will reduce N_2O emissions, and by doing so reduce a key greenhouse gas that is a key driver of global warming.

Lettuce cultivars were bred for production under non-limiting water and non-limiting N fertilizers. For the lettuce industry to sustain itself in California, lettuce cultivars must be adapted to use less water and N fertilizers. Breeding cycles are long; six to eight years are typically required to develop and release a new cultivar. Complex traits, such as NUE and WUE, are challenging to improve because they are controlled by many genes and the expression of these traits affected by environmental conditions in the field. Thus, identifying key genetic components and selecting loci to improve NUE and WUE in lettuce will increase the efficiency in developing and releasing cultivars with improved NUE and WUE. The overall goal of this project was to use genetics to improve water and N uptake in lettuce and develop germplasm and selection tools to facilitate development of lettuce cultivars with improved water and N uptake.

This project built upon the 2013 Specialty Crop Block Grant Program (SCBGP) Project 50: *Towards Sustainability of Lettuce Production Through Breeding Approaches to Increase Water and Nitrogen Use Efficiency*. The 2013 SCBGP Project 50 goal was to map WUE and NUE using carbon and N isotope discrimination in a bi-parental mapping population of lettuce. In the field trials, significant genetic variation in NUE and WUE was observed among genotypes indicating the potential for improvement through breeding and selection. A second objective was to map these traits as quantitative trait loci (QTL) and develop DNA-based markers to select for NUE and WUE on the basis of isotope discrimination and leaf N content. Field studies and sampling in grower's fields indicated significant environmental influence on these traits (especially NUE) and indicated assessing the genetic potential would require alternative methods. Multiple QTL were identified on several linkage groups with effects ranging from 13 to 24 percent of the variation observed in the biparental mapping population. The 2013 SCBGP Project 50 identified and developed genetic markers that are associated with WUE and NUE in a biparental mapping population. It established the potential for breeding to improve these traits and the foundation to begin work to identify mechanisms and genes underlying the QTLs. Using funds from the California Leafy Green Research Board and the California State University (CSU) Agriculture Research Institute, project staff developed plate assays to measure the genetic potential of root growth and N uptake and screened the bi-parental mapping population. Variation in genetic potential was observed and this plate assay was established as a viable tool to screen for improved NUE and WUE based on root growth. The limitation to the 2013 SCBGP Project 50 was that the variation was limited to the two parents of the mapping population and genotypes with better NUE and WUE may exist. This current project built on the work completed by prior project by applying the approaches developed to screen a diverse collection of germplasm to develop maps that will facilitate selection for improved whole-plant N and water uptake and enhanced root growth.

Project Approach

Screen diverse lettuce germplasm for N and water uptake using field and controlled-environment gel-plate assays:
The diverse germplasm included 63 entries of non-domesticated species from the genus *Lactuca*, including *Lactuca serriola*, *Lactuca saligna* and *Lactuca virosa*, stem lettuce (*Lactuca sativa*) and other unimproved *Lactuca sativa* accessions, 89 commercial cultivars, and the top 1 percent of high N accumulating genotypes. The commercial cultivars served as a benchmark of N uptake and assimilation, and is representative of the germplasm being utilized by growers and that being developed by breeders.

Previously, project staff observed large environmental variation in N uptake and assimilation in the field. To minimize the risk of selecting the wrong genetic lines, project staff developed a controlled environment gel-plate assay that minimized environmental variation. This allowed to implement a parallel approach to identify superior genotypes, i.e., field and controlled environments, to identify the best genotypes to serve as parental lines to develop mapping populations, genetic-based breeding tools and improved germplasm.

Field-based screenings were performed at the Yuma Agricultural Center in Yuma, Arizona in the fall of 2015. The controlled environment gel plate screenings were performed at Cal Poly Pomona during spring and summer 2016. For both studies, N was supplied at the equivalent of 140 kg N per hectare (125 lbs N per acre), approximately one-half the recommended commercial rate for the lower desert production areas. At market maturity (field plants) or 20-21 days after planting (plate assays), leaves of each genotype were collected, dried, weighed, and sent to the University of California (UC) Davis stable isotope lab for leaf N content and 13C and 15N isotope analysis. For plants grown in the gel plate-controlled environment conditions, root

growth and growth rates were recorded.

Outcome: For each genotype evaluated in the field and under controlled gel-plate assays, leaf C and N concentration, C13 and N15 isotope discrimination were obtained. The genotypes were ranked by leaf N concentration, with separate rankings for field and controlled environment gel-plate assays. Baseline data were obtained for leaf N concentration of commercial cultivars grown in the field and under controlled environment plate assays.

Develop F2 populations: F2 populations were developed to make selections of superior plants to advance to the F3 generation, and to construct genetic maps that would allow identification of loci associated with NUE and WUE. Using rankings from the field and controlled environment screenings, 17 genotypes with the best N uptake and assimilation were identified and were used as parents to make crosses. A total of 558 crosses were made from 57 unique parental combinations. Seeds were collected, planted and putative F1 plants from these crosses were grown in a greenhouse between April 2017 and September 2017 to produce seed for F2 populations. To verify that seed from crossed plants represent a true F1 hybrid and were not selfed, the DNA was extracted from F1 plants and subjected to amplified fragment-length polymorphism (AFLP) analysis. Plants of all putative F1 hybrids were grown in the greenhouse, allowed to self, and the seed collected and cleaned. Seed from a single confirmed F1 hybrid were used to produce a single F2 population.

A second set of F2 populations were derived from crosses based on the parental performance under the controlled environment gel plate assays. Following crosses among the best performing genotypes (part of the 558 total crosses described above), the plants were grown in the greenhouse, DNA extracted and F1 hybrids were verified using AFLP analysis. Plants of all putative F1 hybrids from these crosses were grown in the greenhouse, allowed to self, and the seed collected and cleaned. Only seed from confirmed F1 hybrids were considered for use in the F2 screens in the next step.

Outcome:
Superior genotypes, defined as having the highest leaf N concentration, were used to make crosses. F1 hybrids were confirmed, planted and allowed to self. Seed from individual plants were collected and were used in the next step.

Phenotype F2 populations and make selections:
Field Evaluations: A low-nitrogen lettuce trial was planted at the Yuma Agricultural Center (September 2017) to select plants from segregating F2 populations for advancement to the next generation. Seed from seven F2 populations, 100 commercial cultivars, and 64 diverse genotypes consisting of non-domesticated *Lactuca sativa*, *L. saligna*, *L. serriola*, and *L. virosa* accession were sown and the plants were grown under non-limiting water and low nitrogen (50 percent of commercial production recommendations, equivalent to 140 kg N / ha). At market maturity (November 15-16 and November 27-28, 2017) plants were evaluated in the field for horticultural attributes (bolting, leaf appearance and color) and leaf samples were taken to determine leaf N uptake. Commercial cultivars were included in the trial to establish benchmarks of nitrogen uptake of the commercial cultivars. Diverse non-domesticated *Lactuca* genotypes were included to establish genetic variation in the gene pool and for comparison against the F2 breeding materials. Leaf samples of three representative plants from each genotype were collected and processed (dried, pulverized, weighed and encapsulated) at Cal Poly and sent to the UC Davis stable isotope lab for N concentration and isotope analysis.

Field selections: For each F2 population, the racemes of 200 plants were bagged and seeds were allowed to mature. Bags retained the seed of genotypes that were prone to seed shattering. In March 2018, the bags from genotypes with mature seed were collected from the field and taken to the lab at Cal Poly Pomona for cleaning, labeling and storage in -20 °C freezers. Using the data from the UC Davis stable isotope lab, plants with the highest leaf N concentration will be advanced to the F3 generation.

Controlled environment gel-plate assays: Two F2 populations were screened in a controlled environment by sewing two hundred seeds from each population into gel-plates with a defined complete salt medium supplied with 0.5x N. After 21-24 days, leaves were collected from each plant, processed (oven dried, pulverized, weighed and encapsulated) and sent to the UC Davis stable isotope lab for N concentration and isotope analysis.

Controlled environment selections: For each F2 population, 200 plants were transplanted to pots and moved to a greenhouse where they were grown. Plants were allowed to flower, bagged and seeds were allowed to mature. Seeds of individual plants were collected from the bags, cleaned labeled and stored in -20 °C freezers. Using the data from the UC Davis stable isotope lab, plants with the highest leaf N concentration will be advanced to the F3 generation.

Genotyping and genetic analyses of F2 populations and diverse germplasm:
Seven F2 populations were evaluated for leaf N concentration and horticultural attributes. Using those criteria, four populations were selected as having a combination of high leaf N concentration and desirable horticultural characteristics. These four F2 populations were selected to advance to marker development using tunable genotyping-by-sequencing (tGBS). DNA was taken from the plants of the four F2 populations, parental lines, and diverse genetic materials and sent to an outside vendor (Data2Bio) for library construction and sequencing. The sequencing data is being used to construct genetic maps and identify loci contributing to N uptake and assimilation and the horticultural attributes that were evaluated for each population.

Outcome:
High-density linkage maps for four F2 populations are being used to identify loci associated with improved NUE and WUE. The loci linked to these traits will be useful for marker assisted selection in our program and shared with plant breeders to use in their own programs to improve NUE and WUE in lettuce.

Grower/industry presentations: Results of the research were shared with lettuce industry professionals including an oral presentation at the California Leafy Greens Research conference, attended by approximately 150 attendees. The project was picked up by several popular press venues, including the “American Vegetable Grower” and “Western Farm Press,” and a radio interview.

Outcome:
Industry meetings: Oral presentation of research results to growers, breeders and lettuce industry personnel at the California Leafy Greens Research Board, 2016-2017 Annual Research Conference, 14 March 2017, Pismo Beach, California. Attendance was reported at approximately 150 people.

Popular press:
Trade magazines and/or websites:

American Vegetable Grower, Lauren Maria Alexandar (author), published 6 December 2017. "Scientists Aim to Improve Nitrogen, Water Use Efficiency in Lettuce; American Vegetable Grower", http://www.growingproduce.com/vegetables/scientists-aim-to-improve-nitrogen-water-use-efficiency-in-lettuce/

A slightly different version was released on 5 January 2017: http://www.growingproduce.com/vegetables/scientists-aim-to-improve-nitrogen-water-use-efficiency-in-lettuce-2/

Western Farm Press: "Growing lettuce with less nitrogen, water?" Published 24 March 2016, and online at: FarmProgress: https://www.farmprogress.com/vegetables/growing-lettuce-less-nitrogen-water

Radio: Interview with California Ag Today, broadcast 2 April 2016.

Academic Conferences:
Results of the research were presented in January 2017 and January 2018 at two academic conferences, the Plant and Animal Genome Conference, held in San Diego, California. In addition to academic scientists, the meeting is attended by industry breeders and scientists.

Professional meetings:
Poster presented at the Plant & Animal Genome XXV Conference in San Diego, California--January 14-18, 2017. Title: Exploitation of natural variation in nitrogen uptake and metabolism to develop lettuce cultivars with improved nitrogen use efficiency. Poster/Abstract P0934.

Poster presented at the Poster presented at the Plant & Animal Genome XXV Conference in San Diego, California--January 13-17, 2018. Title: Introgression of alleles from non-domesticated germplasm to improve nitrogen use efficiency in lettuce. Poster/Abstract P1172.

This project did not benefit commodities other than specialty crops, specifically lettuce.

Goals and Outcomes Achieved

The overall goal was to develop cultivars project improved N and water uptake to reduce resource consumption, minimize environmental impact and enhance sustainability of lettuce production. In order to accomplish this long-term goal, this project had several objectives or performance goals:

1. Develop two F2 populations that serve to improve nitrogen and water uptake and efficiency, one population based on whole-plant field selections and another population based on controlled environment gel plate assays.
   Activities that were conducted to achieve this included:
   i) Screen diverse lettuce germplasm for N and water uptake using field and controlled-environment gel-plate assays. Germplasm was grown under low N conditions and superior genotypes were identified.
   ii) Using superior genotypes, make crosses to generate F1 hybrids. Confirm hybrids.
   iii) Self F1 hybrids to create F2 populations.
   iv) Outcome: Seven F2 populations were established and screened for N uptake and assimilation.

2. Establish benchmarks of commercial germplasm for N uptake and assimilation.
   i) Commercial germplasm was screened in the field and under controlled environment conditions; once in fall 2015 and a second time along with the F2 populations.
   ii) Outcome: Benchmarks were established for commercial germplasm based on two growing seasons.

3. Establish a high-density genetic map.
   i) DNA was extracted from four F2 populations, parents and diverse genetic materials.
   ii) Tassel, R/QTL and JMP Genomics were used to filter and create maps.
   iii) Outcome: Four high-density genetic maps were created.

4. Disseminate results of research.
   i) Results were shared with the lettuce industry (growers, breeders and industry personnel) at the California Leafy Greens Research Board, 14 March 2017.
   ii) Results were shared at two professional meetings, attend by academic and industry scientists including industry plant breeders, at the Plant and Animal Genome Conference in January 2017 and January 2018 (details provided above, under “Project Approach”).
   iii) A report was prepared and disseminated to the industry breeders that cooperated with the study by providing seed. Breeders from 3 Star, Enza Zaden, Nipomo Seeds, Riijk Zwaan, and Syngenta participated, and each received a report of the research including background, results of the field trials that included ranking of their materials relative to all 1600 genotypes, mapping results and the next steps of the research project.

The long-term goal was to develop cultivars with improved nitrogen and water uptake to reduce resource consumption, minimize environmental impact and enhance sustainability of lettuce production. In order to accomplish this, project staff have developed segregating populations with improved N uptake and assimilation compared to commercial cultivars. The project staff have also developed high-density genetic maps that will facilitate breeding using marker assisted selection. These genetic tools and segregating populations will be used by breeders and the program to select and advance materials to achieve our long-term goal.

The project goals included:
1) Develop two F2 populations that serve to improve N and water uptake and efficiency, one population based on whole-plant field selections and another population based on controlled environment gel plate assays.
2) Establish benchmarks based on 40 commercial cultivars grown for one production year.
3) Establish one high-density genetic maps.
4) Sharing results through industry meetings and providing reports to breeders that shared seed.
For each of those listed above, project staff exceeded the goals:
1) Developed nine F2 populations to be used to improve N and water uptake and efficiency; seven F2 populations were based on whole-plant field selections and two F2 populations based on controlled environment gel plate assays.
2) Established benchmarks based on 89 commercial cultivars grown for two production years.
3) Established four high-density genetic maps.

Major successful highlights of the project:

Nine F2 populations were developed and assessed for N uptake and assimilation by two different screening methods. The populations were derived from genotypes that displayed high N uptake and assimilation, and each of the F2 populations performed better than the commercial cultivars that served as a benchmark comparison.

Four high-density genetic maps were created and SNP markers associated with leaf N concentration and other WUE, NUE and horticultural characteristics were identified to aid breeders in improving NUE in their breeding programs.

Alleles favorable for N uptake and assimilation are missing from commercial cultivars but are present in non-domesticated germplasm.

Beneficiaries

Beneficiaries of this project include seed companies that have active lettuce breeding programs in California for the California/Arizona production regions. Several seed distributors have product development personnel conducting evaluations and developing proprietary materials. Although beyond the life of this project, project staff anticipate that eventually, most cultivars in California and Arizona will carry alleles that improve both WUE and NUE.

Beneficiaries of this project include 27 seed companies that have active lettuce breeding programs in California for the California/Arizona production regions. Several seed distributors have product development personnel conducting evaluations and developing proprietary materials. The latest data indicated there are 1,486 farms growing commercial lettuce across over 44,515 hectares (110,000 acres) in California. If these growers follow recommended N rates (280 kg N/hectare or 250 lbs N/acre) then approximately 12,464,200 kg N is being applied. The best performing germplasm in the F2 populations is over 20 percent more efficient in N uptake and assimilation than commercial cultivars when grown under low N. There is substantial potential to reduce N inputs and improve the economic and environmental outlook for the lettuce industry in this regard.

Lessons Learned

The biggest challenges in meeting the project timelines was obtaining N data from outside labs in a timely manner. Moving to the next stage of the project required relatively quick turnarounds to receive these data. The project staff required N concentration and N15 data to select the top 1 to 2 percent of the genotypes to serve as parents and to select plants to advance to the next generation. Because project staff were not able to receive the data sooner, all plants in the F2 population had to be grown, maintained, bagged and seed collected, labeled and stored until project staff received the data from these labs.

The project staff anticipated that outreach of the project and dissemination of results would be facilitated through a website that was able to track visits and by proxy, to use this as a metric to gauge interest. The project staff were not able to do that and are working with IT support to address that issue and work on content to build a more effective website.

Additional Information

See Attachments:

1. F2 populations_NUE (photograpsh of the F2 populations growing in the field)

2. F2 populations_NUE_frequency distributions (distributions of leaf N concentration for F2 populations, diverse germplasm, parental lines and commercial cultivars.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 46	**Project Title:** Real-Time Irrigation Metrics for Improved Water Use Efficiency in Orchards and Vineyards	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SBC15046	**Date Submitted:** December 2018
Recipient Contact: Christine Stockert	**Telephone:** (530) 754-7144	**Email:** cmstockert@ucdavis.edu

Project Summary

California grape, almond, and pistachio perennial crop growers have been under increasing demands to reduce irrigation water use. These three permanent crops occupy more than two million acres of irrigated land; this can be extended to include most permanent specialty crops that are irrigated, thus approximately three million acres. Understanding water footprints of these crops and increasing water use efficiency without site-specific reductions in yield and quality is critical to the continuing success of these crops when confronted with drought and a regulatory environment that continues to place increasing pressure on water resource provision.

California confronts unprecedented drought of epic proportions and specialty crop growers need tools to allow them to use water more conservatively. Increasing water demand means California specialty crop growers must immediately find ways to conserve water. Water conservation using the tool outlined in this proposal will solely enhance the competitiveness of orchard crops and vineyards by reducing costs of purchased surface water sources and costs of pumping well water. It will further reduce management costs by providing an easy to use tool, also being designed specifically for grapes and nut crops. A savings of $150 to $330 per acre on irrigation water use is projected, thus further enhancing competitiveness of these specialty crops. Central Valley grape growers use two to three acre-feet of water per acre and nut crops use upwards of four acre-feet. These crops are solely representative of most California woody perennial specialty crops. Water conservation is critical to the success of growers of such specialty crops as stricter water use regulations, including ground water use, are imminent.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

This project focused on improving the understanding of the water cycle in almond, pistachio, and wine grapes. Efforts were focused on three key relationships crucial in modeling the water cycle of each of these crops at regional scales: a) the relationship between canopy size and the normalized difference vegetation index (NDVI) (from Landsat, CERES, and SkyBox), b) the relationship between soil moisture (SM) and plant water stress, and c) the relationship between plant water stress and stomatal conductance. The relationship between plant water stress and remotely-sensed thermal imagery (CERES) was also examined.

In 2016, efforts were focused in almond and pistachio fields west of Madera, California. Surface renewal towers were set up to measure evapotranspiration (ET). Neutron probe access tubes were installed to measure SM. Flowmeters were installed to measure irrigation. Lastly, periodic data was collected on canopy size and tree water stress during the 2016 growing season. One of the project targets was to obtain successful metrics for both tracking cover crop and vineyard/orchard canopy development (LAI, growth rate) over the growing season showing good agreement with VSIM. Since VSIM used the NDVI to estimate canopy growth, the

team measured how well the NDVI correlated with canopy growth and then used those relationships within the VSIM model to calculate canopy growth. Good correlations were found between ground-based measurements of leaf area index and the Landsat 8 NDVI (30m pixel resolution) in both almonds (y=-0.0773x2 + 0.4502x + 0.1523, R2 = 0.92) and pistachios (y=-0.2093x2 + 0.6405x + 0.0866, R2=0.79). Good relationships were also found between canopy radiation absorption and the Landsat 8 NDVI (R2=0.96 in almonds, R2=0.89 in pistachios). NDVI from the SkyBox/TerraBella satellite (5m resolution, owned by Google in 2016) was well-correlated to the Landsat 8 NDVI in almond and pistachio on the four dates in 2016 that the Skybox/TerraBella NDVI were acquired (almonds y = 1.13x – 0.31, R2=0.94; pistachios y = 1.14x – 0.30, R2 = 0.63). Good correlations were also found between measurements of SM (neutron probe) and measurements of stem water potential in both almonds (y=0.1178x^-2.406, R2=0.81) and pistachios (y=395.23x + 64.64, R2=0.71). Interestingly, the relationship between SM and stem water potential was curvi-linear in almonds, while linear in pistachios.

In 2017, efforts were focused on improving understanding of the water cycle of wine grapes. Project efforts were linked with the National Aeronautics and Space Administration-funded GrapeX Project in the Borden Hills northwest of Lodi, California. The primary goal was to test these critical water balance algorithms discussed above, which were previously implemented for wine grapes in the VSIM model using funds from the California Department of Water Resources. The project team was able to use the data collected from the eddy covariance towers installed at this site, as well as the SM, flowmeter data, leaf water potential (LWP) data, and stomatal conductance data to test the VSIM model at this site. The VSIM model allowed for historical analysis. The project team was able to utilize the 2016 data set acquired (from the GrapeX project) to calibrate VSIM, and then to test VSIM in 2017 using the data collected as part of this project. VSIM estimates of vineyard ET compared favorably with ET measurements in 2016 (R2 = 0.79) and 2017 (R2 = 0.55). VSIM estimates of LWP and SM compared favorably with 2017 measurements (R2 = 0.83 for LWP; R2 = 0.95 for SM). Importantly, it was found that the rooting depth calibration used at this wine grape site was constant across 2016 and 2017 – this was significant in that it indicated that once the VSIM model was calibrated to a site using measurements of LWP, subsequent years would have fewer LWP measurements to check the calibration, provided that all input data sets were accurate.

A prototype mobile phone application was developed that could access and display data from the VSIM vineyard database. The application linked to VSIM vineyard datasets stored on the VSIM Amazon Cloud server. The application summarized the results of the most recent VSIM forecast for each vineyard and block in the user's portfolio. Starting from the login page, the user would enter their email address and password. This information was relayed to the VSIM server and based on the user's login credentials, links were passed from the VSIM server back to the application. The links were updated each time the VSIM server ran a forecast for a particular vineyard and provided the data to the application. For each vineyard, two links were passed back from the VSIM server API; a link to a json file containing the VSIM forecast output data and a link to a png image and pgw file of the latest Landsat NDVI image of a specific vineyard. This allowed participating wine grape growers to access the most recent water balance information for each vineyard block (irrigation to date from flowmeters, estimated LWP, and estimated soil water deficit). The application also displayed the most recent Landsat 8 satellite image for the vineyard. The prototype application was tested with nine participating growers. An earlier version of this application had been provided to a subset of growers, however it became clear that additional software development would be needed. Initial feedback collected from growers indicated a favorable response to the application as a data delivery mechanism.

Two publications have resulted from this project to date:

Bellvert, J., H. Nieto, S. Baram, K. Adeline, D. Smart, & P. Zarco-Tejada, 2017. ESTADO ACTUAL DE LA TELEDETECCIÓN TÉRMICA PARA LA DETECCIÓN DEL ESTADO HÍDRICO DE LOS CULTIVOS. 1-4. 10.25028/CNRiegos.2017.A10.

Bellvert J., Adeline K., Baram S., Pierce L., Sanden B.L, and Smart R.D., (2018). Monitoring crop evapotranspiration and crop coefficients over an almond and pistachio orchard with remote sensing images, manuscript in preparation.

This project focused on wine grapes, almonds, and pistachios. All grant expenditures were tracked to ensure that grant funds were used solely to enhance the competitiveness of specialty crops.

The principal investigator provided overall project coordination, laboratory resources and facilities, and laboratory personnel in support of canopy and water flux measurements at all study sites. The principal investigator also chose the 2017 study sites and initiated grower contacts for access. Grower partners provided access to almond and pistachio orchard study sites near Madera, California in 2016 and in Turlock, California. Wine grape study sites near Lodi, California in 2017 (including EJ Gallo and GrapeX project).

Significant contributions of project partners included measurement of canopy parameters and water fluxes in almonds, pistachios, and wine grapes (University of California, Davis Smart Lab, University of California, Davis, and California State University, Monterey Bay), relating ground-based measures of canopy size to the NDVI (University of California, Davis Smart Lab, California State University, Monterey Bay), testing and development of key algorithms to be used to simulate water fluxes in the VSIM model (California State University, Monterey Bay), and development and testing of the prototype mobile phone application (California State University, Monterey Bay).

Goals and Outcomes Achieved

Data was collected on the NDVI, ET, SM, canopy size, and LWP. This was done to develop relationships between satellite-derived NDVI and canopy size, SM and plant water stress, and plant water stress and stomatal conductance, to adapt the VSIM model to simulating the water footprint of almond and pistachio crop types. The project team was able to test and confirm that the VSIM model could successfully model the water balance of wine grapes and provide actionable estimates of vine water stress in wine grapes. These data were made accessible via a prototype mobile phone application.

These same data were collected in wine grapes to test previously-developed VSIM model algorithms and to verify and apply the VSIM model in simulating the water footprint of wine grapes near Lodi, California. The project team was able to test and confirm that the VSIM model could successfully model the water balance of wine grapes and provide actionable estimates of vine water stress in wine grapes. These data were made accessible via a prototype mobile phone application.

Another of the project's targets was that the VSIM model would improve water demand, water status, and soil water consumption prediction by 10 to 30 percent as compared to existing comparative database derived from 2015-2016 and 2016-2017 ground based data. Irrigation amounts estimated by VSIM were compared to existing grower practices using split-block irrigation trials across seven Lodi-area Cabernet Sauvignon blocks

in 2016. The VSIM subblock received weekly irrigation amounts forecasted by the VSIM model while the grower practice subblock received whatever amount of water the grower felt was appropriate. Results varied by block based on grower practices and the user-defined seasonal water stress targets set in VSIM. Across six of the seven VSIM sub-blocks, water savings were observed ranging from 4 to 31 percent (15-110 gallons per vine) over the growing season in the VSIM subblock compared to the adjacent grower practice subblock. In the seventh block, the VSIM subblock required 27 percent more water (85 gallons per vine) than the grower practice subblock. Wine grape yields declined by 16 to 34 percent in the VSIM blocks where water savings were observed relative to the grower practice. However, wine grape quality was enhanced in these same VSIM blocks by 21 to 41 points (based on the Gallo Quality Index (GQI), which is a cumulative quality score from 0-100 points based on several individual metrics of wine grape chemistry and color). In the seventh block were increased water use was observed in the VSIM subblock relative to the grower practice, 59 percent increase in yields were obtained (from 7.1 to 11.8 tons per acer) with lesser reductions in quality (from a GQI of 79 to 57, which was still suitable for the grape buyer).

Lastly, the project aimed to have over 25 growers of orchard and vineyard perennial crops register at VSIM sever for use of irrigation smartphone application. A prototype mobile phone application was developed that accessed NDVI imagery and water balance calculations from the VSIM Amazon Cloud server for display by growers in the field. Key water footprint algorithms were developed that will allow the VSIM water balance model to be adapted to almonds and pistachios. The project team plans to continue to develop and test the robustness of these algorithms across a range of sites in California after the duration of the grant. The project team also plans to expand the use of the VSIM model and mobile phone application in these crop types, as well as others.

The project team was able to meet most of the goals of the project to improve the understanding of the water footprints of almond, pistachio, and wine grape crops. The early version of the mobile phone application required additional software development to fix problems that occurred during implementation. The team experienced limited success in attracting growers to use the VSIM smartphone application. Therefore, 9 out of the 25 growers were able to register for use of the irrigation smartphone application. The project team was able to get growers to sign up for and receive weekly VSIM forecasts via email as a pdf file. In 2018, 50 growers received weekly VSIM forecast updates encompassing 42 vineyards and 110 wine grape blocks. As for almonds, the algorithms required to adapt the VSIM model from wine grapes to almonds was developed. However, the project team will need to seek additional funding to advance development of the VSIM software and provide weekly forecasts to almond growers.

The team was also successful in determining how satellite imagery and modeling could be used to present the water footprint to growers via a mobile phone application. Regarding the aerial imagery, the project team found it more difficult than anticipated to work with private-sector providers of aerial imagery. These companies were either undergoing changes and acquisitions (e.g. Skybox/Terrabella) or in some cases with CERES, the calibrations provided were not as useful as hoped. The data from this study was useful in quantifying key water balance relationships in almond and pistachio crops but extrapolating these findings to customize the VSIM model to deliver water footprint information to growers will require additional data collection and testing across a range of almond and pistachio sites that span climate, soil, and canopy size differences. Future studies are planned to further pursue this development.

Data sets gathered as part of this project included the characterization of the water footprint in almonds and pistachios in 2016 and in wine grapes in 2017. These data sets included NDVI and thermal imagery, surface renewal measurements, measurements of canopy size (leaf area index, shaded area), neutron probe SM measurements, LWP, and daily irrigation. These data were used to develop and test the VSIM model in these crop types. Future studies are planned to build on this work to continue the development of the VSIM model and mobile phone application in these crop types.

Major successful outcomes of the project included; a) an improved understanding of key water balance relationships in almond and pistachio, and how to adapt the VSIM model water balance algorithms previously developed in wine grapes to these crop types, b) testing of the VSIM model estimates of ET, SM, and LWP in wine grapes, and c) development of a prototype mobile phone application that would allow the grower to access summary data while in the field from the VSIM Amazon Cloud server. These outcomes will help to expand access to the VSIM water balance forecasts in California agriculture, helping to balance crop yields and quality while at the same time helping growers to better monitor and forecast crop water balance requirements.

Presentations of project results included the following:

Bellvert, J., H. Nieto, S. Baram, K. Adeline, D. Smart, & P. Zarco-Tejada, 2017. ESTADO ACTUAL DE LA TELEDETECCIÓN TÉRMICA PARA LA DETECCIÓN DEL ESTADO HÍDRICO DE LOS CULTIVOS. 1-4. 10.25028/CNRiegos.2017.A10.

Pierce, L., and A. Michaelis, 2018. *Winegrape Irrigation Forecasting using the VSIM Model in 2017*, invited presentation given at the Current Wine & Winegrape Research grower outreach meeting, UC Davis, 2/21/18. (50-60 attendees)

Pierce, L., A. Michaelis, M. Alsina, L. Sanchez, D. Smart, H. Ouaknin, R. Vaughn-Davis, T. Stockert, B. Kustas, and T. Wilson, 2018. *Application and Testing of the VSIM Model at Borden*, presentation given at the 2018 GRAPEX meeting, E&J Gallo Winery, Modesto, CA, 3/6/18. (20-25 attendees).

Pierce, L., 2018. *The VSIM Irrigation Forecasting System: How it works, what it provides, and who's using it*, invited presentation given to the Paso Robles Viticultural Technical Group, Paso Robles, CA, 5/8/18. (20-25 attendees)

Bellvert J., Adeline K., Baram S., Pierce L., Sanden B.L, and Smart R.D., (2018). *Monitoring crop evapotranspiration and crop coefficients over an almond and pistachio orchard with remote sensing images*, manuscript in preparation. (15-20 attendees).

Beneficiaries

The wine grape growers in California have directly benefitting from the research conducted in this project through an improved understanding of the water balance of wine grapes, through the testing of the VSIM model, and through the development of the VSIM mobile phone application. A few California wine grape growers had begun to evaluate the VSIM mobile application. The feedback provided at the end of the 2018 season will help to improve the application and the delivery of water balance information to wine grape

growers. Almond and pistachio growers will benefit from the data collection and analysis in this project because it improved understanding of the water footprint of these crops and the foundation of key algorithms needed to implement the VSIM model.

Ongoing outreach efforts focused on the 10 different wine grape-growing companies that had received the weekly VSIM forecasts that estimated plant water stress and forecast irrigation needs across 40 different wine grape vineyards, as well as 2 table grape vineyards (through the California Table Grape Commission). A subset of these growers tested the prototype VSIM mobile phone application. The project team will continue to automate the VSIM software to provide additional growers with access to the VSIM water balance forecasts. The team planned to continue expansion into wine grapes and table grapes, as well as to seek to make the VSIM model forecasts available to growers for irrigation management in almond and pistachio after the duration of the project. This project benefitted a total of 402 growers through presentations and direct interactions.

Lessons Learned

The development of a mobile phone application was new to the project team. Much was learned, including that mobile phone applications must be developed across two different mobile phone operating systems - iOS (Apple) and Android. This doubled the development cost, because mobile phone applications that access device tools (e.g. GPS) will work faster and better when developed in their native environments, in comparison to development in cross-platform languages (e.g. html 5). Also, for future work, the project team will seek to hire an external contractor to do the application programming and development (e.g. via sites like Upwork.com), rather than taking this on internally and having to learn the corresponding program languages etc. to support application development and launch. Additionally, it was learned that complex measurements (e.g. ET) and modelling (VSIM) were only as good as their least reliable input. The use of flowmeters with cellular endpoints (e.g. Badger meter Orion system) was a good way to improve the accuracy of irrigation inputs to the VSIM modeling. But also, must be careful to Quality Assurance/Quality Control any outside data sources used to drive water balance models (e.g. zeroing sprinkler water that gets into the CIMIS precipitation gages during summer).

Given the project timeline and the ending of this project half-way through the 2018 growing season, some data was collected prior to the end of June 2018 (LWP, canopy size), but these data, along with the data needed to drive and test the VSIM model (e.g. meteorological measurements, ETc) will not be processed until early 2019. Although the 2018 data was contributed to the overall GrapeX Project dataset, these data will not be summarized until early 2019, which will require additional funding to be sought.

The project team benefitted from collaboration with the aerial imagery providers during this project. Free imagery of the almond and pistachio sites was provided by TerraBella during the first year of the project. It is recommended that future projects financially incentivize private companies to participate, either through direct payments via project funds or through demonstrating access to new markets. It was more difficult than expected to acquire aerial imagery from the private companies in the later stages of the project, primarily because of internal company changes and the shifting focus of those companies to applications other than agriculture (e.g. security). Some of the imagery provided by these companies was very site-specific and localized, and it was a challenge to them to provide timely, calibrated imagery across large land areas the size

of California. However, as the size of these satellite constellations increase, so will coverage and access to imagery.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 47	**Project Title:** Demonstrating the Economic and Environmental Benefits of Hot Water Pest Eradication	
Grant Recipient: The Regents of the University of California, San Diego County Cooperative Extension.	**Grant Agreement No.:** SCB15047	**Date Submitted:** December 2018
Recipient Contact: James A. Bethke	**Telephone:** (951) 775-7172	**Email:** jabethke@ucanr.edu

Project Summary

The purpose of this project was to replicate in California the successes that researchers and regulators in Hawaii experienced using hot water to eradicate endemic and invasive pests from ornamental nursery stock and reduce the demand and in the case of invasive pests, mandatory application of pesticides. The movement of ornamental plants is often tied to invasive pest distribution throughout the world, and Hawaii is both severely impacted by invasive pests and a prolific shipper of ornamental plant products.

Research conducted at the University of Hawaii led to an acceptable method of treatment that allowed pest free potted nursery stock and cut flowers and foliage to the U.S. mainland and elsewhere. The treatment method is hyper-thermotherapy delivered via hot water. A limited amount of research has been conducted on a wide variety of plant and pest types at the University of Hawaii in the hopes of standardizing the required temperatures to kill unwanted pests and not harm the plant. However, this method has not been used in California on potted nursery crops for the purpose of shipping clean plants or the eradication of pest on incoming shipments. The preferred method has been the application of pesticides or the destruction of infested shipments. The destruction of even small shipments, however, can cost growers tens of thousands of dollars because ornamentals are a high-value specialty crop. A detection of an invasive moth, *Duponchellia fovealis*, back in 2010 in San Diego County cost one ornamental producer nearly $250K in lost revenue and stock. The main objectives of the project were to 1) demonstrate that hot water applications in a specially designed container will effectively kill major pests and invasives of potted nursery stock without damaging plants, 2) perform an economic analysis of the procedure, and 3) determine the impacts of pre- and post-water quality. The impacts of this method, if adopted, is the concomitant reduction in pesticide use, which will lead to reduced pesticide exposure and environmental impact, and a reduction in mandatory plant destruction due to invasive pests.

Regulatory protocols and mandatory pesticide use for eradication are increasing rather than reducing pesticide use, and growers tend to preventively overuse pesticides to kill difficult to control pests to maintain phytosanitary requirements. Some pests in the industry are only nuisance pests, and some growers will use beneficials to control pests. Regulators and customers, however, note the mere presence of arthropods on the plants, and the grower will respond by applying pesticides to clean plants entirely.

The project emphasized the pest management of endemic and invasive pests of potted nursery crops using hot water. The development and verification of the effectiveness of a new tool for the eradication of invasive pests already present in California such as the red imported fire ant, the glassy-winged sharpshooter, the Asian citrus psyllid, European pepper moth, and others. Additionally, it will provide a new pest management tool for managing common but difficult to control pests in ornamental plant production such as the western flower thrips, the American serpentine leafminer, melon aphids, fungus gnats, whiteflies, mealybugs and others.

Lastly, this new tool will also provide a secondary or additional treatment for ornamental plants arriving in the state and found infested with an invasive pest such as snails and slugs and the Coqui frog. These infested plants are often destroyed due to the seriousness of the pest or the lack of legal treatment options for eradication. This new method will provide an option for eradication in lieu of plant destruction. Therefore, a result of the use of hot water therapy in regulatory protocols and for endemic pest control is the concomitant reduction in pesticide use. Further, it will provide a potential control option for those invasive pests where pesticide treatment options do not exist.

This project did not build upon a previous Specialty Crop Block Grant Program project.

Project Approach

The original goals were to replicate the hot water treatment system that is being used in Hawaii, test various ornamental plant types for heat tolerance at selected temperatures, test the efficacy of plant-safe temperatures on selected endemic and invasive pests, provide an economic analysis, and investigate the potential reuse of the water to reduce water use. The goals and work plan were adjusted continuously to complete the first goal, the construction of the unit. Heat tolerance and efficacy testing was only initiated at the end of the project.

Objective 1: Demonstrate the efficacy and plant safety of a hot water treatment unit.
Staff purchased a cargo container, and placed it on a trailer to make it mobile (Attachment 1 - Figure 1). A significant effort was made to prepare the work site to house the unit and provide all the utilities needed to run the unit. A significant effort was made to construct the unit using all of the varied components. The unit was completed in January 2018 (Attachment 1 - Figure 2).

Verification of the ability of the unit to spray water at a specific temperature for an extended period of time commenced in January 2018. Sensors were located within the unit and an electronic controller was installed on the outside to assist with selecting specific temperatures and the verification. Staff began plant safety testing and testing the unit against selected pests of ornamental plants during the last two months of the project (Attachment 1 - Table 1). Some of the testing was unique and had not been tested before, even in Hawaii. The one goal staff were unable to complete was the verification of mortality caused by hot water treatments against invasive pests detected by regulators. Several options presented themselves, but each detection contained reasons why staff could not test the unit or get verifiable data from the infested plants.

Objective 2: Water quality testing and determination of suitability of reuse or irrigation.
Water quality was evaluated before and after hot water treatment; for biological, chemical and physical contaminants. This monitoring provided an indication of any needed water conditioning for the water feed, to ensure reliable, consistent performance. Guidelines for water reuse have been established to identify some important water quality parameters that are important when providing water conditioning or treatment. In general, these guidelines are outlined for physical, chemical, and microbiological water quality parameters of acceptable quality for the intended use. These water quality parameters should be monitored to achieve optimal performance of the hot water treatment system. Staff found that discharge of water from the hot water treatments and modification processes were within Environmental Protection Agency compliance. Water quality monitoring of effluent-runoff from hot water treatment was assessed for secondary use, in accordance with the National Pollutant Discharge Elimination System (NPDES). The NPDES has established guidelines for intended use as irrigation water. Based on these guidelines staff identified minimal conditioning

requirements and appropriate treatment goals to achieve the recommended guidelines and regulation requirements.

One of the chemical quality tests is referred to as the Oxidation reduction potential (ORP) is a measurement of the oxidation power of the water, which increases when using chlorine, chlorine dioxide, and ozone. The physical water quality was assessed by measuring the Total Suspended Solids, $mg \cdot L^{-1}$ (TSS) in the recirculating hot water shower. Staff also evaluated TSS, as potentially degradable organic material which increases the demand for chemical sanitizing treatment and also increases exposure risk to harmful byproducts, especially in the presence of chlorine. Conductivity (EC), $dS \cdot m^{-1}$ was also monitored, for concern of metal corrosion and also phytotoxicity to plants if the concentration of salts is higher than plant tolerance. (Attachment 2 – Table 1)

Objective 3: Economic analysis
Data was gathered from scientific literature and local growers' inquiries to determine the costs of pesticide treatment applications to control pests. Staff also collected data from actual use of the hot water treatment unit during the last few months of the project period. Data collection included labor, costs of plants, water, propane, unit maintenance, etc. An economic comparison between pesticide application verses hot water treatment is presented.

Outreach: Due to the lateness of the unit construction, staff were unable to do much outreach of results. The results that were obtained in the last two months of the project are appropriate for outreach and those data are being prepared. A poster presentation was given at the Entomological Society of America and a presentation about the completion of the unit and preliminary data produced was given in June of 2018, the last month of the project, at the California Association of Pest Control Advisers San Diego Chapter, Nursery Greenhouse Seminar. Additionally, PIs and students presented research and progress reports and put many of the presentations online.

Project Management: Meetings were monthly in the beginning of the project, but when it was obvious that staff were unable to construct the unit without help, the meetings ceased until progress could be made. When the University of California (UC), Merced began participating in the construction, weekly meetings via conference call and monthly face-to-face meetings occurred. Further, Project Investigators (PI) were in constant contact by visiting UC Merced to monitor progress, and by visiting the site and assisting in the construction of the unit in Vista, California.

This project does not enhance the competitiveness of non-specialty crops.

Project partners:
Nursery and Floriculture Advisor. UC Cooperative Extension, San Diego. Role: PI/Project Manager. Coordinated and verified the progress of contractors constructing the hot water treatment unit. Maintained communications among project PIs, Co-PIs and staff. Additionally, wrote and filed reports and analyzed data.

IPM Interim Director and Area Integrated Pest Management Advisor. UC Cooperative Extension, San Diego. Role: Evaluation of plant safety. Due to the lack of a completed unit, was unable to do any extensive evaluations until just before the end of the project. During the project period, however, IPM Director attained

some additional funding related to the project and constructed a steam generating chamber where it was tested on various plants for hyper-thermal therapy. The results from that work are summarized in the report section.

Executive Director (ED). Center for Applied Horticulture Research (CfAHR). Role: Co-PI. ED and staff assisted with unit construction and site preparation and analyzed the pre- and post-treatment water quality. The site preparation turned out to be a significant contribution to the project. Water used in the trials needed to remain on site at the nursery, and it could not flow into nearby greenhouses, which required some trenching. Additionally, the propane tanks used to run the tankless water heaters need to be established on the site at CfAHR and the gas lines need to be buried. The trailer needed leveling and leaning slightly so that the water used in trials would flow out one corner of the unit.

UC Merced. Director of Innovation School of Engineering. Role: In charge of the design framework, prototype testing and system simulation. Conducted think-tank sessions with students who presented best-case scenarios for construction of the unit. These sessions were held in the school of engineering in front of an audience of engineers who challenged the design and testing of unit controls and prototypes on a small scale at UC Merced. They then brought finished units down to CfAHR to be installed on the treatment unit.

Staff Research Associate, UC Cooperative Extension, San Diego. Role: Supervised the project at the CfAHR. Was in charge of the construction of the hot water treatment unit and evaluating the efficacy of selected hot water temperatures against selected insect pests. Was instrumental in the completion of the hot water treatment unit and in making significant adjustments to ensure its proper function. Also instrumental in acquisition of plants and pests for initial testing, reports of which are presented in the report section below.

Department of Agriculture Weights and Measures, San Diego County. Role: Provided data on ornamental plant production industry losses to plant destruction due to infestations of invasive pests.

Cooperator and owner of Altman Plants. The CfAHR resides on the grounds of Altman Plants in Vista, CA. Has donated staff time, nursery space, greenhouse space, and many nursery plants to the project. Paid a staff member on his own time to assemble the gas lines, tankless water heaters and some of the plumbing. Additionally, allowed staff to answer questions about pesticide treatments, costs and pots/acre for the economic analysis.

Owner of Twin Oaks Nursery. Role: Provided sago palm bulbs that were infested with cycad scale, as well as mite infested ivy.

Owner of Kent’s Bromeliads. Role: Provided bromeliads infested with millipedes.

Goals and Outcomes Achieved

Staff were unable to follow the performance plan and achieve performance goals as intended due to the lack of a functioning hot water treatment unit until the last months of the project. Staff had to continuously change the goals in the work plan and adjust finish dates to reflect the difficulties encountered in the construction of the unit. A minimum amount of progress was made on the performance goals toward the end of the project period. Staff did complete some aspect of every objective that is listed in the performance goals.

The long-term goals were to encourage building and use of hot water treatment units by the ornamental plant production industry and California Department of Food and Agriculture (CDFA) regulators in lieu of pesticide use. At this point, staff are only able to encourage the continuation of the project so that proof of concept can be achieved. Another long term goal is to vastly increase the number of plant species and pests tested. The project is temporarily continuing in an attempt to make further progress.

This project's measurable goals included: 1) replication of the hot water treatment system that is being used in Hawaii, 2) testing of various ornamental plant types for heat tolerance at selected temperatures, 3) testing the efficacy of selected hot water temperatures on endemic and invasive pests, 4) Investigate the reuse of the effluent from the use of the chamber, and 5) investigate the economics of the system contrasted with pesticide treatment.

Replication of the hot water treatment system that is being used in Hawaii.
Staff did not anticipate the difficulties they would encounter while building the hot water treatment chamber, and were constantly adjusting the timeline to account for the time it took to build the unit. This portion of the project dominated the timeline, progress, and work plan. Regardless, staff were able to construct a working unit.

Testing of various ornamental plant types for heat tolerance at selected temperatures.
One of the immediate needs under this goal was to test tolerances of the myriad of succulents that have become a very popular plant in the retail market. Staff were not able to do as much testing as they would have liked due to the delay in construction, but testing has commenced, and staff intend to continue testing beyond the project end. Each test performed during the later stages of this project, however, contained a hot water tolerance component, which provided some very good information for ornamental plant producers willing to use one of these testing chambers.

Testing the efficacy of selected hot water temperatures on endemic and invasive pests.
Again, due to the delay in construction, staff were unable to complete as many trials as they would have liked, but were able to begin the process and will continue the trials beyond the end of the project. Staff maintained contact with project partners at San Diego County Ag Commissioner’s office in the hopes of testing the hot water treatment against an invasive pest, on plants that were slated for destruction, but were unable to find a suitable infestation following the completion of the unit and before the project end date. It is still a hope that staff will be able to do some testing against invasives in the near future. Staff were, however, able to test several temperatures against a variety of pests on many different plant types.

Investigate the pre- and post-treatment water quality.
One of the PI’s performed pre- and post-treatment analysis of the water quality to determine if the water used in the system may affect plant health, and if the effluent (Attachment 1 - Figure 3) could be reused without harming the plants.

Adequate water quality may be difficult to sustain as a result of increased organic load from media and plant residues during the shower. Water quality parameters are considered in terms of any adverse effects on the equipment, water delivery or plant health issues. The assessment determined an appropriate use for the waste effluent discharged from the hot water treatment. After multiple runs, staff found the water of suitable quality for secondary use in irrigation systems, if appropriate level of water treatment is provided.

Investigate the economics of the system contrasted with pesticide treatment.
PIs at UC Merced performed an analysis of the economics of the hot water treatment system and contrasted the results against the use of pesticides to control or eradicate invasive and endemic arthropod pests. The analysis shows that the labor involved in moving plants into and out of the chamber is more costly than the labor to spray plants/acre. However, the cost per plant of the hot water treatment is actually lower than the cost of pesticide treatments due to the costs of materials. Additionally, there is a positive impact from a worker exposure consideration and to the environment that is not considered in the economic analysis.

The current unit was used in several trials at the end of the project, and data indicate that the unit maintained approximately 120ºF/48.9ºC (N=24, range 115.5-123.3, mean = 119.5, STD = 2.3) as determined by four sensors strategically located within the chamber. Each sensor provided a recording every minute for six minutes during one of the tests. To date, staff have completed eight trials in the chamber using a total of 116 plants in seven different plant species and against three different pest species. A cost analysis comparing pesticide treatment application to hot water therapy has been provided. An analysis of the pre- and post treatment water quality was completed. On a per pot basis, pesticide treatments cost approximately $0.033/pot, whereas, it would cost approximately $0.027/pot using the hot water treatment therapy. Staff demonstrated the efficacy of the unit to a specific grower with a nuisance pest problem is a best case scenario for this project. If successful, the word will spread very rapidly throughout the ornamental horticulture industry in San Diego County. Grower demonstrations and demonstrations to the county Ag Commissioner and staff will further enhance the economic value of this project.

Staff have a completed and working hot water treatment unit housed at the Center for Applied Horticulture Research on the grounds of Altman Plants in Vista, California. The number and type of trial is described and summarized in Table 1. The following results were obtained using the unit prior to the end of the project period. No observable damage occurred on English Ivy at 110-113°F, however, this trial was the first use of the unit, and the chamber did not hold a constant temperature (Attachment 1 - Figure 4). Further, live mites were present following treatment, so a higher temperature and longer exposure period will be necessary to control mites on ivy.

Lavender is a more herbaceous plant and severe damage was observed when treated with 120°F for eight minutes (Attachment 1 - Figure 5). No observable damage occurred to two species of Pinwheel when treated at 120°F for eight minutes (Attachment 1 - Figure 6). Minor damage was observed on sago palms and jade fingers and moderate damage was observed on Pencil cactus. Minor damage to bromeliad leaf and bract tips was observed following treatment with hot water at either 113°F/45°C for five minutes or 120°F/48.9°C for six minutes.

Data for the mean number of live ($p=0.05$, Bartlett Chi-square = 18.41, df = 3, P = 0.00036) and dead millipedes per pot are significantly different ($p=0.05$, chi-square = 10.37, df = 3, P = 0.01569). For example, the mean percentage (N=14) of live millipedes in untreated, 113°F and 120°F was 78, 3 and 13 percent respectively, and the mean percentage (N=14) of dead millipedes in untreated, 113°F and 120°F was 22, 97 and 87 percent respectively.

It should be noted that temperature and exposure time can be adjusted for each plant to reduce damage due to the hyperthermal therapy. Further, some damage will likely be acceptable because the plants will recover in time. This is especially important when considering that the eradication of an invasive pest can be achieved,

and the plants that would not have been destroyed due to regulatory protocols are saved and recover. All plants that were treated in the chamber by the end of the project period need to be held so that any long-term plant physiological effects can be determined.

In Attachment 1 - Table 2, calculated estimates to treat plants with pesticides compared to hot water are presented, with the assumptions and considerations that are listed in the notes of the table. The number of variables in the production of ornamental plants (acreage, plant types, pots/acre, pesticide costs, labor, seasonality, pest complex, etc.) is exceptional (Newman, J. 2011. Container Nursery Production and Business Management Manual. UC Publication 3540. 329pgs.). As much as possible, however, staff have standardized the data to represent an average grower and their inputs. These variables determine the final costs for pest management, and therefore, a range of possible costs are provided in the table.

The table is developed using available information from the scientific literature and with information provided directly from local growers. Comparisons are also based on pesticide treatment/acre and hot water treatment by the number of plants that can fit in the chamber at one time. Staff also determined the number of plants/acre based on the most commonly used nursery pot/can the #1-can or approximately one-gallon container because the size of pot varies considerably in the nursery industry. Other considerations include the time to treat a plant, which is shorter for pesticide applications resulting in a larger number of plants that can be treated per time frame. Further, the cost of labor in that case is greater than the cost of materials simply due to the number of plants treated. Inputs were minimized and maximized for best and worst case scenarios. Highest costs/acre for pesticide applications is largely based on the costs of pesticides. Some growers can grow plants only using pesticides costing $90/container, whereas, newer generations of pesticides can increase costs up to $1,200/container. Costs per acre for pest control can vary significantly depending on the plant type and pest susceptibility. Highest costs of hot water treatment are largely based on the cost of propane and water. If the water used can be recycled, the costs/acre are reduced significantly. When the water is recycled (best case) in the hot water treatment therapy the minimum costs of treating with hot water ($175/acre) is lower than treating with pesticides in the best case scenario ($202/acre). When the costs of water and propane are maximized, however, the cost of hot water treatments ($386/acre) exceeds those of pesticides ($342/acre).

In the final analysis, the cost of treatment per plant is likely going to be less expensive with the hot water therapy than pesticide applications. Added benefits to the hot water therapy that were not quantified include benefits to the environment and to human health. Other potential benefits may include improved yield, reduced product loss, and regulatory compliance (although these factors are also hard to quantify without long term application).

Beneficiaries

Project staff demonstrated to growers that their infested plants can be treated with hot water, cleared of pests, and damage to the plants was minimal. In the first case, high value sago palms enter the U.S. as a bulb lacking leaves and roots, but they are typically white armored scale infected, which are nearly undetectable. When the grower pots the crop, the scale overtakes the growing plant, and they are nearly impossible to eradicate because many of them are under the flared and overlapping leaf bases. The plants are then considered unmarketable because they do not meet phytosanitary requirements, and the scale cannot be cleaned from the plant without damaging the plant. The white scale has a cover that is hydrophobic and impenetrable by pesticides. Therefore, the grower resolves to destroy the plants rather than spend more money to recover the plants. However, using the hot water treatment system at 120ºF (48.9ºC), the scale is exposed to temperatures

that kill the insect while only causing minor damage to existing leaves. This is good news in that rather than destroying the plants, the plants are cleaned and can recover quickly enough to make them salable.

Secondly, growers are losing customers due to a nuisance pest, millipedes that invade potting media (Latvian peat) because it is a very good food source. The millipedes feed on decaying plant matter and reproduce directly in the pots. The millipede is a native arthropod, but they are attracted to the peat that falls under the benches, and they climb benches to invade pots. Although millipedes are not plant pests, when the plants reach the retail market and the plants dry out a little, the millipedes exit the pots and great numbers of millipedes are found in the floors in the retail market place and retail customers complain. Therefore, retailers demand control of the pests prior to entry into the marketplace. The grower treats under benches with carbamate insecticides on a weekly or biweekly basis to reduce the populations. Project studies demonstrate that the millipedes are killed by 113ºF/45ºC for five minutes or 120ºF/48.9ºC for six minutes with minor leaf and bract damage. Studies are underway to determine a temperature and duration that will not cause damage and yet significantly reduce millipede numbers in pots.

Lastly, one of the largest nursery growers in the nation is one of the largest suppliers of succulents and no studies of the effect of hot water treatments on plant safety have been conducted. Further, succulents are notorious for mealybug infestations. Mealybug infested plants are constantly detected in shipped succulents causing regulators to put a hold on the plants until they are treated prior to release. Project studies demonstrate that a hot water treatment at 120ºF (48.9ºC) for eight minutes does moderate damage to pencil cactus but not to pinwheel succulents. More research is needed to determine the temperature and duration is necessary to clean plants of mealybugs and cause no plant damage.

These successes are significant and will assist in convincing both growers and regulators that this method is an effective method that meets phytosanitary requirements and reduces pesticide use.

Currently, the cooperating growers have benefited from this research. It is very difficult to estimate the potential economic impact, but staff did estimate that there is a cost savings and other added benefits to using the hot water treatment verses a pesticide treatment application. Additionally, the research that demonstrates that the hot water treatment will significantly reduce millipedes in pots of bromeliads is very encouraging, and the grower who is a strong advocate of worker safety is open to using the unit or building one for themselves.

There are 2,959 ornamental horticulture producers in California with a value totaling $4.5 billion.

Lessons Learned

One of the benefits of cooperating with the Ag engineers at UC Merced was the practical experience students gained from all the interaction and discussions about the project. Although the PIs and staff at UC Merced were engaged in the project, utilizing the students conserved funds while enhancing student experience and course work. PIs at UC Merced and students presented several new ideas to the project including a drop-down system that adjusted the height of the spray nozzles to the height of the plants, and they installed this in the unit (see Attachment - Figure 3). They recommended within water tank sensors, so staff could monitor the temperatures, which ultimately led to the insulation of the hot water tank to conserve heat. They recommended the use of more energy efficient electronic devices, which in the original plans from Hawaii were outdated. They determined that the electrical load was not sufficient with the generator purchased. They determined through calculations that the number of nozzles in the chamber did not match the water pressure

within the lines. This practical experience and the knowledge gained about the nursery industry enhanced the advancement of students and improved the design of the hot water treatment chamber.

The greatest negative impact on this project was the complications experienced in connecting all the components so that they talk to each other and so that pipe diameters, water pressure, electrical load, etc. worked together. As such, staff sought the assistance of outside contractors to help put everything together and get the unit working. The complications in finding a consultant that met all of the state and UC requirements were daunting and very time consuming. In hind sight, engaging engineers at the beginning of the process would have been much more efficient. Ag engineers at UC Merced assisted with the issues experienced, but the distance between UC Merced and the actual treatment unit in Vista, California caused additional delays in unit construction. Staff believe that constructing the unit at UC Merced and verifying its use prior to moving the unit to the nursery industry in San Diego County would have been a better plan.

Staff anticipated successful results against endemic and invasive pests, but providing a potential non-pesticide solution to a nuisance pest in the ornamental plant production industry was unexpected, and it suggests that there are other possible uses for this unit in the industry that have yet to be identified. Staff conducted research on solutions for the millipedes in potted bromeliads in the past and provided growers with a pest management program that solved their problem for a while, but it was very costly and required treating large areas of greenhouse floor and not the plants on top of the benches. The pesticide was also one of the more toxic pesticides still available in California and presents some level of worker exposure. Hot water therapy could be successfully used to eliminate millipedes in pots just prior to plant shipment thereby removing the need for any routine pesticide applications and the associated costs. It is common for growers to move the plants from benches to loading docks prior to shipment. The extra step of moving them into the chamber for treatment would be nominal in comparison to the routine pest management program.

The main problem staff experienced in this project was the complication of unit construction and the policy requirements that outside contractors were required to comply with. Regardless of the possession of all of the parts and plans, the construction still required qualified contractors to assemble. Some parts on the parts list obtained from units built in Hawaii were no longer available and some technologies had advanced requiring new electronic components, which in turn changed the electrical load requirements.

Additional Information

Due to the lack of data from the project until the very end, no publications were produced during the project period. Photographs taken during the project period are provided in Attachment 1. A poster presentation was given at the Entomological Society of America and a presentation about the completion of the unit and preliminary data produced was given in June of 2018, the last month of the project, at the California Association of Pest Control Advisers San Diego Chapter, Nursery Greenhouse Seminar. Publically accessible information on the engineering and construction of the hot water treatment unit was placed online by UC Merced PIs as part of the Capstone projects at UC Merced. A Capstone project is usually the final course in engineering at UC Merced where the students use all the knowledge they have gained and demonstrates his mastery of the subject matter. All documents are accessible in a folder (https://drive.google.com/open?id=1rDW-80Eo9eX1lVhBVHbYHsgLT_CDWBS4) and include the following: 1)) Poster entitled "Plant Hot Water Pest Treatment" as well as 2) Capstone Power Point presentation entitled "Hot Water Pest Eradicator" presented at the UC Merced 2017 Fall Innovate to Grow (Engineering Capstone Projects Final Review and Expo https://innovatetogrow.ucmerced.edu/2017-fall-

capstone-projects), 3) Capstone Design Final Report, Hot Water Pest Eradicator, 11pgs., 4) Poster presentation entitled "Hot Water Pest Treatment" as well as 5) Capstone Power Point presentation entitled "Sustainable Solutions in Agriculture" presented at the UC Merced 2018 Spring Innovate to Grow (Engineering Capstone Projects Final Review and Expo, https://innovatetogrow.ucmerced.edu/teams/capstone-idc-spring2018), 6) Capstone Design Final Report, "Design of Improved Spraying and Pulley System", 26pgs., and 7) Economic analysis entitled "Hot water system - Operational Cost Estimate".

USDA Project No.:	Project Title: Development of Molecular Markers for Selection of Lettuce Genotypes with Resistance to Verticillium Race 1	
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Project Summary

The Salinas and Pajaro Valleys of coastal central California are the most important lettuce-producing regions in the United States (Simko et al. 2014). Among the top disease concerns for lettuce in the area is Verticillium wilt caused by the fungus Verticillium dahliae (Atallah et al. 2011, Inderbitzin and Subbarao 2017), which is a soilborne pathogen with a wide host range that also includes artichoke, cotton, eggplant, hops, potato, sunflower, tobacco and tomato (Pegg and Brady 2002, Inderbitzin and Subbarao 2014). Two races of V. dahliae occur in central California, race 1 and race 2 (Vallad et al. 2006). Race 1 of the pathogen carries Ave1 that is recognized by Ve1 in resistant tomato (de Jonge et al. 2012). Ve1 encodes an extracellular leucine-rich repeat receptor-like protein (Kawchuk et al. 2001, Wang et al. 2010) that is widespread in mosses, ferns, monocots and dicots (Song et al. 2017). In addition to Ve1, tomato also contains the closely linked paralog Ve2, but only Ve1 confers resistance to V. dahliae race 1 (Fradin et al. 2009). This is similar to hops, potato and wild eggplant, where only one of the Ve homologs, HLVe1-2A, StuVe1 and StoVe1, respectively, elicits resistance to race 1 (Song et al. 2017). However, in cotton, both Ve homologs, GbaVd1 and GbaVd2, illicit resistance to V. dahliae race 1 (Chen et al. 2017). In lettuce, resistance to V. dahliae race 1 is conferred by a single dominant gene (Verticillium resistance 1, Vr1) located on linkage group 9 (Hayes et al. 2011a). The resistance allele originated from Batavia-type cultivar La Brillante. It is unclear, however, how many Vr genes are located at this locus. Race 2 of V. dahliae is also present in central California, though it is less prevalent than race 1 (Gurung et al. 2014). Adequate resistance against race 2 has not been found in lettuce, although some lettuce genotyped showed delayed foliar symptoms of the disease (Hayes et al. 2011b, Sandoya et al. 2017).

The goals of this study were to identify the lettuce Vr allele(s) that play a role in resistance to V. dahliae race 1 and to develop polymerase chain reaction (PCR)-based assays for marker-assisted selection. For this purpose, the research team analyzed sequenced genomes of cultivars La Brillante (resistant to V. dahliae race 1) and Salinas (iceberg type, susceptible to V. dahliae race 1). Subsequently, sequencing and/or allele-specific PCR screens were performed on 150 additional lettuce accessions to identify the Vr alleles that are present exclusively in resistant phenotypes.

Race 1 is widely prevalent in the Salinas Valley and as noted above, it is among the top disease concerns in the area, particularly for lettuce growers. This research allowed for speedy screening for race 1 resistance in lettuce, facilitating breeding of resistance.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The goals set forth in the project were met and very substantially exceeded. The research team proposed to genome sequence 16 lettuce assemblies but managed to generate 61 assemblies. The 61 assemblies, together

with the pathogenicity data about resistance and susceptibility to race 1 that was generated in this study, served as the basis for identifying the Vr1 allele originally described in the cultivar La Brillante, is being present in all resistance accessions, and absent in all susceptible accessions. A PCR assay was then developed based on the La Brillante Vr1 allele sequence, and the assay predictive ability was then confirmed by testing with an additional 90 accessions with known virulence data. The assay contains a DNA control, which is a primer pair that targets a gene that is present in all lettuce varieties. That way, there are no false negative results due to poor DNA quality.

In detail, the following activities were performed during the course of this project: 1. organized database of pathogenicity tests that were previously performed on lettuce accessions, 2. grown plants from 129 accessions in greenhouse, 3. collected tissue and extracted DNA from the 129 accessions, 4. selected 61 lettuce accessions for genome sequencing from both resistant and susceptible groups and representing all major lettuce types (iceberg, Romaine, leaf, butterhead, and batavia), 5. prepared genome sequencing libraries for 61 lettuce accessions, 6. performed genome sequencing for 61 lettuce accessions, 7. performed genome assembly of 61 accessions, 8. performed Vr gene searches across all 61 genomes and two other lettuce genomes that were publicly available, 9. aligned DNA sequences of all Vr genes with the help of phylogenetic analyses, 10. designed Vr gene-specific PCR assays targeting gene-diagnostic regions of 500-1,000 base pair (bp), 11. determined the presence of Vr genes in all 129 lettuce accessions using the PCR assays, 12. performed phylogenetic analyses of Vr genes, 13. performed association test to determine the relationship between resistance to Verticillium wilt and presence of Vr genes among the 129 lettuce accessions, 14. designed diagnostic simplex or multiplex PCR assays targeting Vr genes to screen for lettuce resistance to Verticillium wilt, 15. validated diagnostic PCR assays across all 129 lettuce accessions and selected the best assay for release to industry, 16. developed HRM-based assay to identify the functional copy of Vr1 gene in lettuce, 17. deposited genome sequence data into public database (available in GenBank at https://www.ncbi.nlm.nih.gov/bioproject/PRJNA478460).

Lettuce accessions used for genome sequencing and PCR analysis:
A total of 152 lettuce accessions representing all major types of cultivated lettuce (Batavia, butterhead, iceberg, Latin, leaf, oil, romaine, and stem) were analyzed. The majority of accessions (111) were from the United States Department of Agriculture, Agricultural Research Service (USDA-ARS) lettuce collections at Salinas, California; the remaining accessions were from a variety of sources, including Salinas, the previously sequenced cultivar.

Pathogenicity tests:
Experiments were conducted in a field infested with *V. dahliae* race 1 located at the USDA-ARS station in Salinas, California. All 152 accessions were direct-seeded in a randomized complete block design with three replications. Each plot was 7 m long and consisted of two seed lines on 1 m wide beds standard for lettuce production in coastal California. Plant spacing was approximately 28 cm between seed lines and 30 cm between plants within a seed line. All field trials were maintained using standard cultural practices for coastal California lettuce production. Plants were evaluated for disease incidence after reaching harvest maturity. Ten plants from each plot were uprooted. Disease incidence was assessed by cutting taproots longitudinally and recording the number of plants exhibiting the yellowish-brown discoloration of root vascular tissues that is typical of Verticillium wilt. Absence of *V. dahliae* race 1 in cultivars with race 1-resistant genotype was confirmed by plating surface-sterilized symptomatic root tissue on NP-10 semi-selective agar medium and PCR screening any resulting isolates with *Ave1*-specific primers.

DNA extraction:
DNA was extracted using FastDNA SPIN kit (MP Biomedicals, Solon, OH, USA) for most lettuce accessions and with the CTAB method for La Brillante accession 10G364-1. For the FastDNA SPIN kit method, up to 100 mg seeds (~ 100 seeds) or freeze-dried leaf tissue was crushed in liquid nitrogen with a mortar and pestle, and DNA was extracted according to the manufacturer's instructions for plant material. DNA quality was assessed using gel electrophoresis (0.7 percent agarose gel), a NanoDrop spectrophotometer (Thermo Scientific, Wilmington, DE, USA), and a Qubit Fluorometer (Thermo Fisher Scientific, Waltham, MA, USA) as per the manufacturers' instructions. DNA extraction for *V. dahliae* followed the same FastDNA SPIN kit protocol except that CLS-Y solution was used as suggested by the manufacturer.

Genome sequencing and assembly:
For La Brillante accession 10G364-1, three genomic libraries were constructed, one with 180 bp insert size (with in-house protocols) and two Nextera (Illumina, San Diego, CA, USA) 2 and 7 kb mate-pair libraries. All libraries were sequenced in an Illumina Hi-Seq 2000 for 100 + 100 paired-end reads. Reads were directly imported into AllPaths-LG v49856 and assembled using default parameters. Both mate-pair libraries were aligned to the AllPaths-LG assembly using BWA v0.7.4 and these alignments were fed into SSpace v3.0 together with the assembly to perform further scaffolding.

For the remaining accessions, DNA was sent to Novogene (Beijing, China) for library preparation (insert size 350 bp) and sequencing on Illumina HiSeq 4000 machines to generate ~800 M PE150 reads that provided approximately 25x whole genome coverage. Reads obtained from Novogene were further processed to remove low quality sequences using bbduk from the BBMap suite v33.65. This removed sequences with a quality score below 20 from both ends of the read and eliminated reads that had less than 50 bp after trimming. Genome assemblies were generated using MEGAHIT version 1.0.6 or MaSuRCA version 2.3.2. MEGHIT was generally run with default settings and sometimes with meta-sensitive or bulk options in effect. MaSuRCA settings were insert size = 350 and standard deviation = 50, GRAPH_KMER_SIZE = 101, USE_LINKING_MATES = 0, LIMIT_JUMP_COVERAGE = 300, CA_PARAMETERS = cgwErrorRate = 0.15 ovlMemory = 4 GB, KMER_COUNT_THRESHOLD = 1, NUM_THREADS = 40, JF_SIZE = 10000000000, and DO_HOMOPOLYMER_TRIM = 0. Assembly statistics were generated using the shell script stats.sh of BBMap version 37.68.

Ve gene identification and naming:
The expressed sequence tag marker QGD8I16.yg.ab1 at the *Verticillium resistance 1* (*Vr1*) locus in lettuce that has sequence similarity to the *Ve* genes of tomato was used to query the genome assemblies of *V. dahliae* race 1 susceptible cultivar Salinas (assembly version 8, available at https://genomevolution.org/coge/GenomeInfo.pl?gid=28333) and race 1 resistant cultivar La Brillante, using local nucleotide BLAST v. 2.6. The *LsVe* sequences from cultivars La Brillante and Salinas were then used to query the remaining lettuce genome assemblies using BLASTn. Sequence alignments were generated with MAFFT version 7.309 using default settings. Phylogenetic analyses were performed with PAUP 4.0a (build 159) using the maximum parsimony criterion, the heuristic search option, and 10 random addition replicates. Bootstrap branch support was based on 1,000 random addition replicates. Default settings were used otherwise. Protein domains were annotated using the InterPro website (https://www.ebi.ac.uk/interpro/).

PCR assays:
La Brillante *LsVe1L* and *LsVe4L*-specific PCR assays were performed. Each assay was a multiplex assay with two *LsVeL*-specific primers and a plant DNA control with two additional primers specific to the lettuce 4-hydroxyphenylpyruvate dioxygenase-encoding gene (*HPPD*), which has been used as the reference gene in real-time PCR assays.

The entire project only benefitted the lettuce industry. The molecular marker information that can be used for marker-assisted selection (MAS) is being distributed to the stakeholders through individual meetings, conference presentations, and submitted manuscript.

The principal investigator and project lead selected lettuce cultivars, organized and performed pathogenicity tests, co-wrote manuscript. The project's co-lead provided leadership in pathogenicity test evaluation, co-wrote manuscript. The research scientist performed DNA extractions, data analyses and wrote manuscript.

Goals and Outcomes Achieved

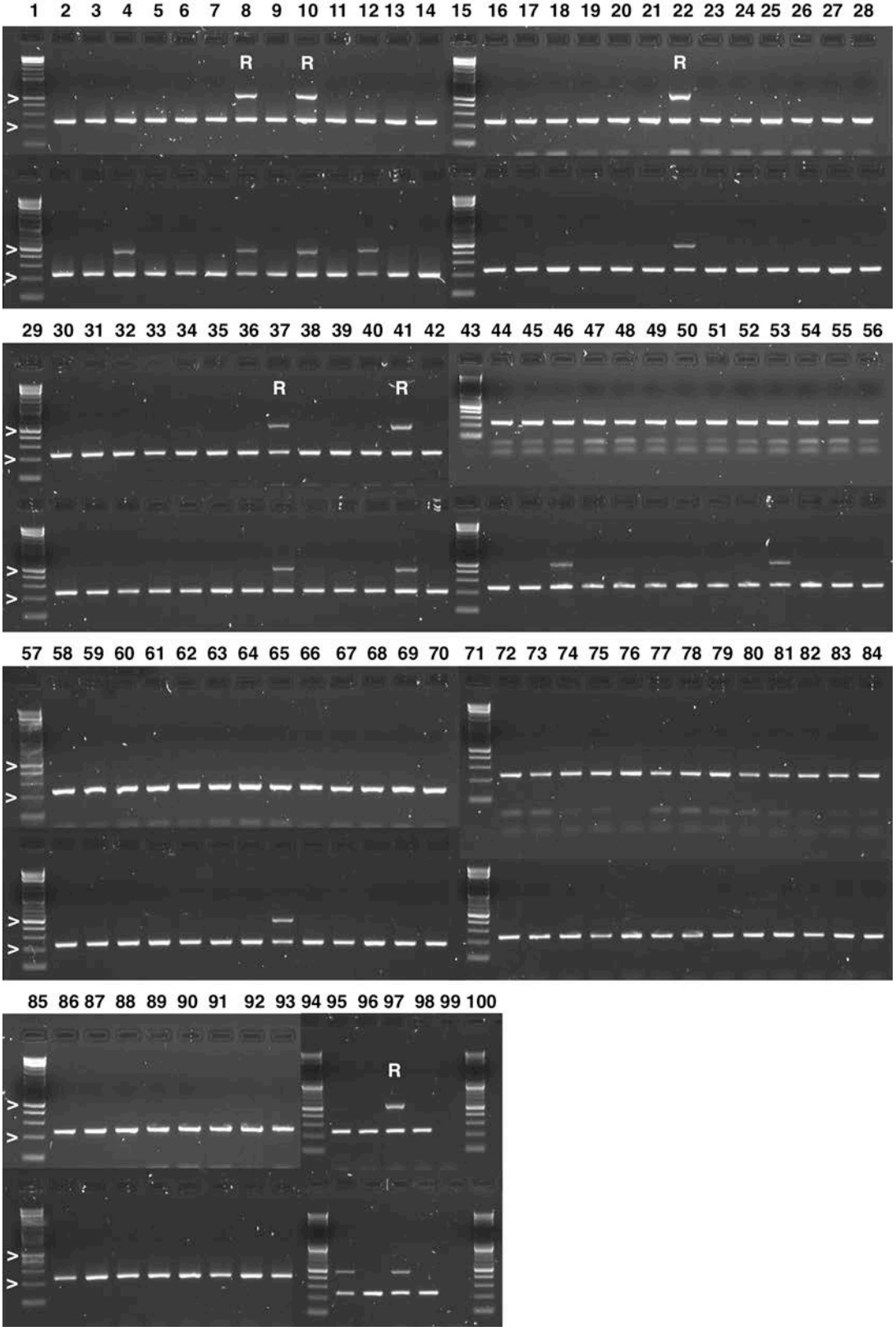
Activities included selection of lettuce cultivars to represent all major types of lettuce, planning and performing of plant pathogenicity tests, DNA extraction, DNA sequencing analyses, performance of phylogenetic analyses, design of diagnostic PCR assay and manuscript writing.

The outcomes measures were short term, therefore all achieved.

The manuscript titled "The *LsVe1L* allele provides a molecular marker for resistance to *Verticillium dahliae* race 1 in lettuce" has been submitted to BMC Plant Biology in March 2019. The results were nationally presented at the California Leafy Greens Research Program (CLGRP) meetings in March of 2018 and 2019 in Pismo Beach, California. The target audience at the CLGRP meeting were experts involved in all aspects of lettuce research (universities, government organizations, and private industry), production (growers), breeding (seed companies), processing (post-harvest processing companies), and extension (farm advisors, extension specialists). Approximately 200 attendees were at the meeting. The results were internationally presented at the International Congress of Plant Pathology (ICPP) in Boston in August 2018. The target audience at the ICPP meeting were mostly plant pathology experts from all around the world. Approximately 3,000 attendees participated at this meeting. The title of the presentation was "PCR assay for *Verticillium dahliae* race 1 resistance in lettuce based on genome sequencing of 61 accessions".

Baseline data is the confirmation that the developed PCR assay is 100 percent accurate in predicting race 1 resistance. This is illustrated in the below figure (Figure 1) that shows PCR results from 90 accessions that were not sequenced. Numbers indicate lane numbers that represent DNA size standards (first lane of each gel) and the different lettuce accessions. For each accession, the top gel of each pair of gels shows results of La Brillante *Vr1* screen, which is diagnostic for race 1 resistance, the bottom gel shows the results of the La Brillante *Vr4* screen, which does not correlate with race 1 resistance. Resistant accessions (based on field evaluations) are marked with 'R'. Amplicon sizes are indicated by '>' and correspond to 200 and 500 bp, respectively. Size standard used is 2-log ladder. The *LsVe1L* resistance allele is distinct from five other copies of the *Vr* allele identified in tested lettuce cultivars (Figure 2). The most closely related *Ve* genes for resistance to Verticillium wilt can be found in other *Asteraceae* species, such as artichoke and sunflower (Figure 3).

Figure 1. Results of the PCR analysis using allele specific assay developed in this project.



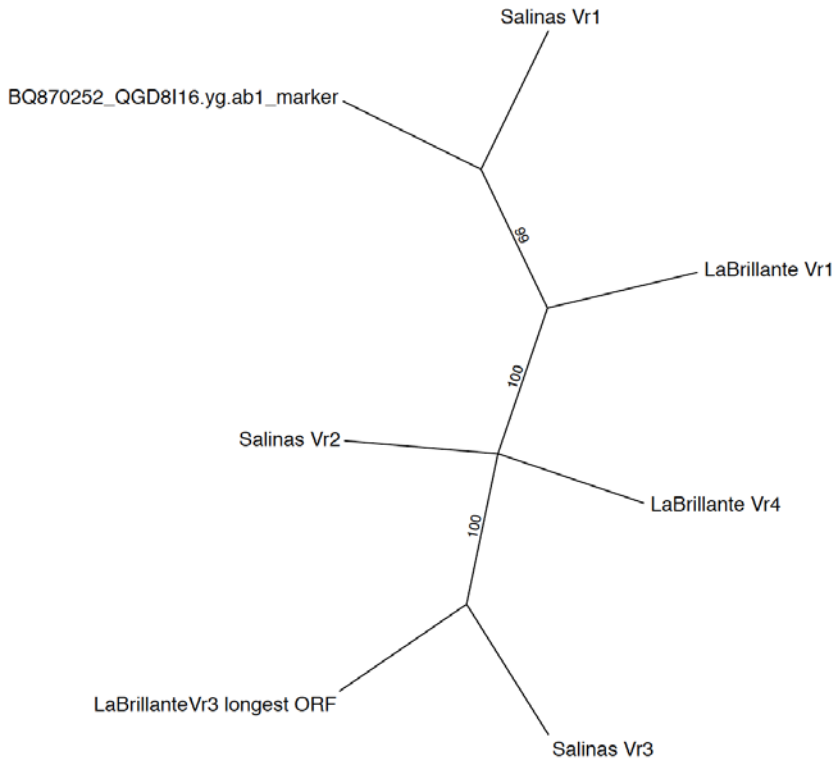


Figure 2. Unrooted parsimony bootstrap tree of cultivar La Brillante and Salinas *Vr* alleles. The topology shows that *Vr1* alleles plus BQ870252_QGD8I16.yg.ab1 marker (GenBank accession BQ870252) group together with maximum statistical support, the *Vr3* alleles group together but La Brillante *Vr4* and Salinas Vr2 alleles do not. Bootstrap supports above 70 percent are indicated by the branches.

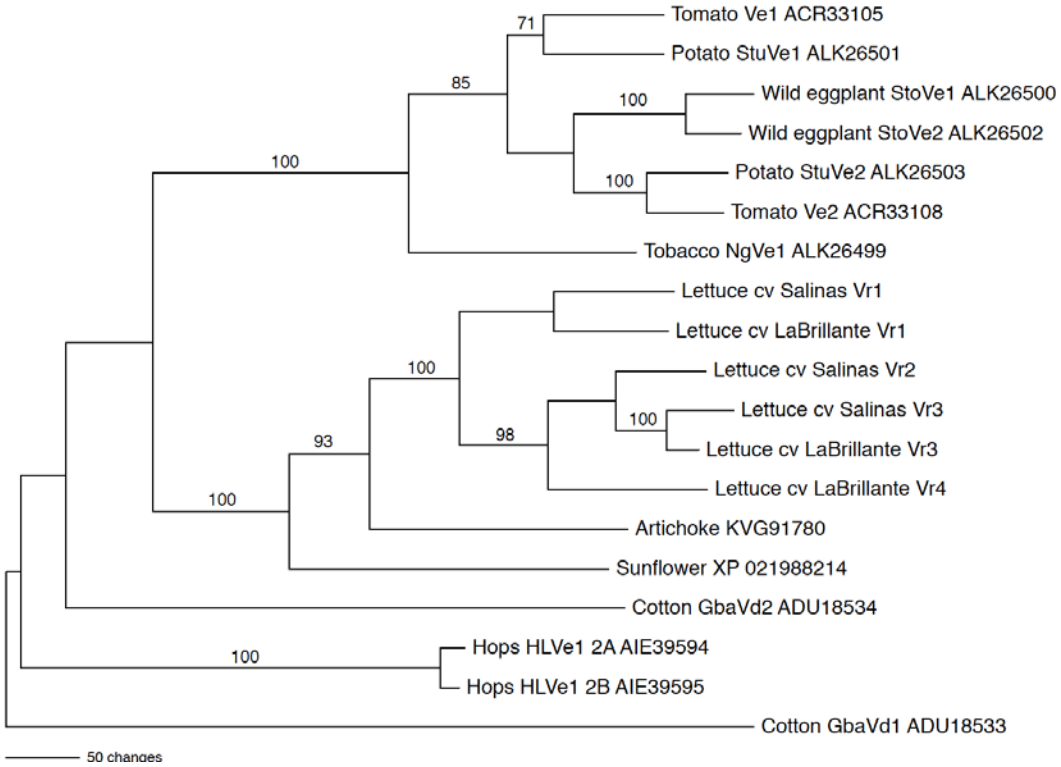


Figure 3. Phylogenetic tree of cultivars La Brillante and Salinas *Vr* allele amino acid sequences and homologs from other plant families using maximum parsimony. One of two most parsimonious trees are shown measuring 3,492 steps, tree is midpoint rooted. Taxa names consist of species names followed by gene names, GenBank accession numbers are also provided for sequences from other studies. Bootstrap supports above 60 percent are shown by the branches. Branch lengths are proportional to changes along the branches and scale is provided.

The major successful outcomes of this project are development of the race 1-diagnostic PCR assay, the sequencing and submission of 61 lettuce accessions to the National Center for Biotechnology Information (NCBI), writing of a manuscript, and presentation of the results at the CLGRP and ICPP meetings.

Lettuce industry is highly concerned by the effect of Verticillium wilt disease on lettuce production in the major lettuce producing areas of U.S. Therefore, development of cultivars with resistance to Verticillium wilt race 1 disease is one of the top priorities identified by the industry. Molecular marker assay developed in the course of this project will likely be adopted by all (or at least a vast majority of) lettuce breeding and biotechnological companies. This assay will likely very significantly improve the accuracy of testing (to 100 percent), time needed for testing (from several years to a few hours), and labor intensity (a lab test that replaces years of field work).

Beneficiaries

The groups and other operations that benefited for the completion of this project's accomplishments are lettuce growers, breeders, packing companies, and eventually also consumers.

The number of beneficiaries affected by the project's accomplishments are:

Plant breeders: All lettuce breeding companies are expected to adopt this PCR-based assay in their breeding program (~20 plant breeding and biotech companies).
Packing companies: ~10
Growers: ~120 in Salinas and Pajaro Valleys (estimate from CLGRP).
Consumers: ~200,000,000

Lessons Learned

There were no major negative experiences associated with this project, everything went as planned or exceeded expectations. On the positive side, the research team was surprised how far DNA sequencing costs had fallen to allow the team to sequence nearly four times more lettuce accessions than predicted. This allowed the team to cut down on PCR screening and Sanger sequencing of non-genome sequenced accessions.

There weren't any unexpected outcomes or results that were an effect of implementing this project. All results show perfect match between plants phenotype and genotype, and thus can be immediately implemented by the lettuce industry.

All goals were achieved and substantially exceeded.

The project was highly successful, and results are well accepted by the industry and stakeholders. Final steps in preparing the manuscript were somewhat delayed due to moving of two post-doctoral research associates to new jobs. However, despite moving to new jobs, both former post-doctoral associates did their best to provide critical information and perform crucial writing needed for finishing of the manuscript.

Additional Information

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CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
49	Testing Efficacy of Anthraquinone as a Vole Repellent in Citrus	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB15049	**Date Submitted:** December 2018
Recipient Contact: Yevgeniy Gnedash	**Telephone:** (530) 752-4513	**Email:** yggnedash@ucdavis.edu

Project Summary

Citrus is a very important group of specialty crops in California with total acreage (over 231,000 acres in 2012) and revenue (over $1.25 billion in 2012) ranking among the top 20 of all specialty crops in 2014. Recent United States Department of Agriculture (USDA) estimates of vertebrate damage to California's specialty crops suggest that approximately 3 percent of California's total citrus acreage is damaged. Vole damage can be even greater in other tree fruit (4.4 percent) and nut crops (4.2 percent), indicating a serious need to mitigate this damage to maximize production and revenues. Voles are a species for which the development of efficacious control methods is currently needed. An integrated pest management (IPM) approach is typically the most effective damage mitigation approach for most vertebrate species. However, some species, such as voles, have few effective options to mitigate damage in agriculture (primarily habitat modification, exclusion, and poison baiting). Although poison baiting can be effective in many crops, it has limited utility in citrus. Baiting is only allowed during the nonbearing season of most crops, yet the nonbearing season is extremely limited or completely absent in some citrus crops. As such, an alternative control option would be highly beneficial to citrus growers. Recent research with anthraquinone (an avian repellent) proved effective at deterring vole consumption of grain. Further field testing was warranted to determine if an anthraquinone repellent could be an effective management option to limit tree girdling as well. Therefore, the project team set out to evaluate the efficacy of an anthraquinone-based repellent for mitigating girdling of citrus by voles. In addition to anthraquinone-based repellent, if the use of vegetation management could be combined with an anthraquinone application to further reduce girdling damage.

Voles can cause substantial damage to citrus, as well as grapes and other tree fruit and nut crops. An IPM strategy that incorporates multiple management tools, including rodenticides, works best to mitigate rodent damage, but management options are quite limited in citrus given that fruit is on the tree almost the entire year, thereby effectively eliminating the use of rodenticides within citrus groves. Additionally, there has been a push to ban the use of rodenticides in many settings in California (e.g., Assembly Bills 2596, 1687, and 2422), further highlighting the need for a new tool to manage voles in citrus. The use of a repellent such as anthraquinone could prove to be a much needed tool to more effectively manage this vole damage. Furthermore, combining the use of a repellent with vegetation management has the potential to further reduce damage, which would clearly build upon the goal of developing an IPM approach for managing voles in citrus.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The original project efforts centered on finding appropriate field locations. To this end, 23 Cooperative Extension Advisors were contacted to be on the look-out for potential field locations, along with the Fresno,

Alameda, Contra Costa, and Yuba Counties Agricultural Commissioner's offices for additional assistance. Project needs for field sites were advertised in agricultural newsletters and trade magazines. From this network, 11 different fields were identified that were thought to merited investigation. Unfortunately, none of the sites were appropriate for this study. They either did not have voles like they thought, had voles in the past but not currently, or had too few voles to be able to effectively test for efficacy (i.e., effect size would have been too low to detect a difference between treated and untreated trees). Vole populations tend to cycle, and in some years, numbers can be very low. As such, test timeframes were adjusted to study repellent efficiency.

The project plan was then developed to test the impact of anthraquinone and the presence of vegetation around the base of trees on vole girdling activity. For this portion of the study, twenty 3.3 (meter) m × 2.1 m tubs (referred to hereafter as mesocosms) were used to house two voles and eight clementine mandarin trees, with half of the trees planted with abundant vegetative growth around the trees, and the other half of the trees planted in a portion of the enclosures devoid of vegetation (Figure 1). Mesocosms were randomly assigned (10 each) to receive the anthraquinone treatment or remain without treatment (i.e., control). Voles were captured in artichoke fields, hedgerows, and in a vineyard. Vole damage was monitored for five to six weeks after release in the mesocosms. This approach allowed the project team to determine the impact of the repellent and vegetation management on vole damage in citrus trees during summer and winter/spring seasons.

Collectively, anthraquinone treatments were found to be highly effective. Research observation showed a 90–100 percent reduction in vole girdling damage to anthraquinone-treated trees when compared with untreated trees across both seasons, regardless of the presence or absence of vegetation around the base of the trees ($P < 0.001$; Figure 2). When combined with anthraquinone treatments, the absence of vegetation around the base of trees further reduced vole damage during summer ($P = 0.059$), with no girdling damage ever observed when anthraquinone was applied to trees planted in areas with no vegetation present (Figure 2). Similar vegetative impact during summer for non-treated trees ($P = 0.143$) was not detected. Likewise, there was no detection of an impact from vegetative cover during spring for either control or anthraquinone-treated trees ($P \geq 0.558$; Figure 2), indicating that anthraquinone was the sole factor influencing girdling activity during this sampling period.

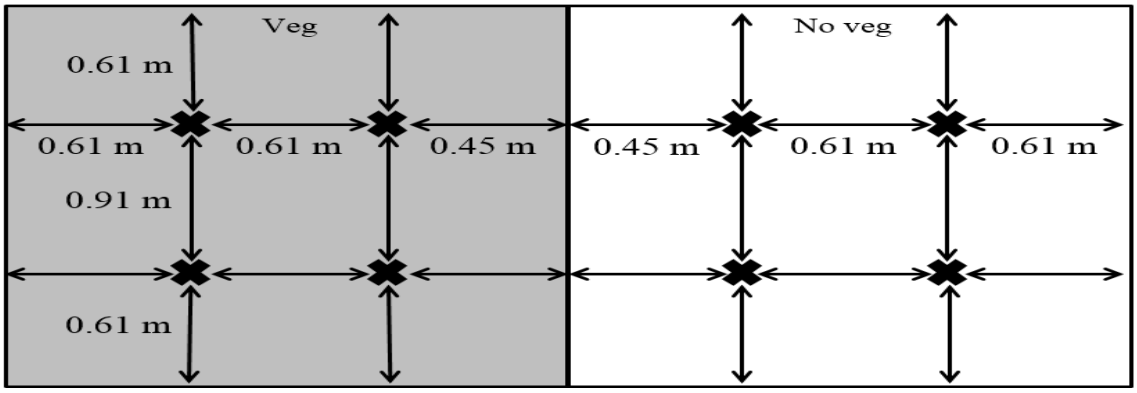

Figure 1. Plot layout for vole mesocosms. X's indicate tree locations. Shaded areas represent the half of the mesocosm that was vegetated, while the unshaded portion represents the non-vegetated half. Vegetated portions were allocated at random.

A peak in girdling activity in control mesocosms was observed on the fourth week during summer (Friedman test, $\chi 2 = 13.5$, $P = 0.009$), yet no temporal pattern in girdling activity for anthraquinone-treated trees was observed during the same season (Friedman test, $\chi 2 = 4.4$, $P = 0.350$; Figure 3). Also, additional observations did not show a temporal pattern in girdling activity for control or anthraquinone-treated trees during spring (Friedman test, $\chi 2 \leq 8.7$, $P \geq 0.123$; Figure 3). These findings indicate that the anthraquinone treatments-maintained repellency throughout the duration of the project study seasons (summer = five weeks, spring = six weeks).

Collectively, these results indicated that anthraquinone treatments were highly effective irrespective of season or vegetation management. One interesting item of note is that when trees were treated to ~15 centimeters (cm) in height, voles would sometimes climb above the treatment line to girdle trees, but when anthraquinone treatments were extended to 30 cm, the project team no longer observed any girdling damage. It is strongly recommended that applicators treat up to 30 cm to avoid girdling damage above the application boundary.

When combined with anthraquinone applications, vegetation management also reduced girdling damage during summer. In fact, there was no detection that a single tree that was girdled when anthraquinone was combined with vegetation management during summer. This form of IPM could be very successful at reducing or potentially eliminating vole girdling damage during this season. However, since any impact of vegetation management on girdling damage was observed during late winter/early spring was observed, so vegetation management likely has some seasonal limitations.

One of the key factors for successful implementation of anthraquinone as a management tool is long-term repellency. Substantial repellency was detected across the duration of the trial periods (five-six weeks). The project team are in agreement that this repellency results could last longer than the duration of the grant term. This long-term repellency should make applications of anthraquinone both efficacious and cost-effective for citrus growers experiencing girdling damage. The project team had hoped to further test the anthraquinone applications in a citrus grove. However, an appropriate field site was unavailable.

Professionally, project results were presented at The Wildlife Society National Conference in Albuquerque, New Mexico in 2017. This conference is the largest wildlife-centric conference in North America (and perhaps the world), which provided a great opportunity to further disseminate project outcomes to wildlife managers and agency personnel (e.g., USDA Animal and Health Inspection Service, Wildlife Services) that would regularly use this repellent to protect specialty crops throughout the United States. The project team has also presented project outcomes at the Vertebrate Pest Conference in Rohnert Park, California, during 2018, which is the oldest and most prestigious Conference of its kind. This conference is heavily attended by a highly diverse group of scientists, agency personnel, regulators, growers, and pest control operators making this an integral outreach opportunity to reach interested parties. The study results have been published in two peer-reviewed outlets: *Journal of Pest Science*, and the *Proceedings of the Vertebrate Pest Conference*. These highly-read outlets will further exposure to this important research. Once anthraquinone becomes available for use against voles, the results will be added to the California Department of Food and Agriculture Vertebrate Pest Control Handbook. These outreach efforts will continue for years to come as this management strategy becomes adopted by interested parties not only locally, but globally as well.

The project also assessed the willingness of growers to use anthraquinone as part of an IPM program. To this end, a survey was developed and was distributed through eight newsletters and two e-mail blasts to identify grower willingness to adopt the use of anthraquinone applications and vegetation management in an IPM program for vole management in appropriate specialty crops. The respondents were overwhelmingly supportive of their use with 96 percent likely to try out anthraquinone should it be registered and 100 percent of respondents willing to use vegetation management to reduce vole girdling damage (n = 68). Given this positive response, it is anticipated that a substantial positive impact from registration of anthraquinone as a vole repellent in citrus and other appropriate specialty crops.

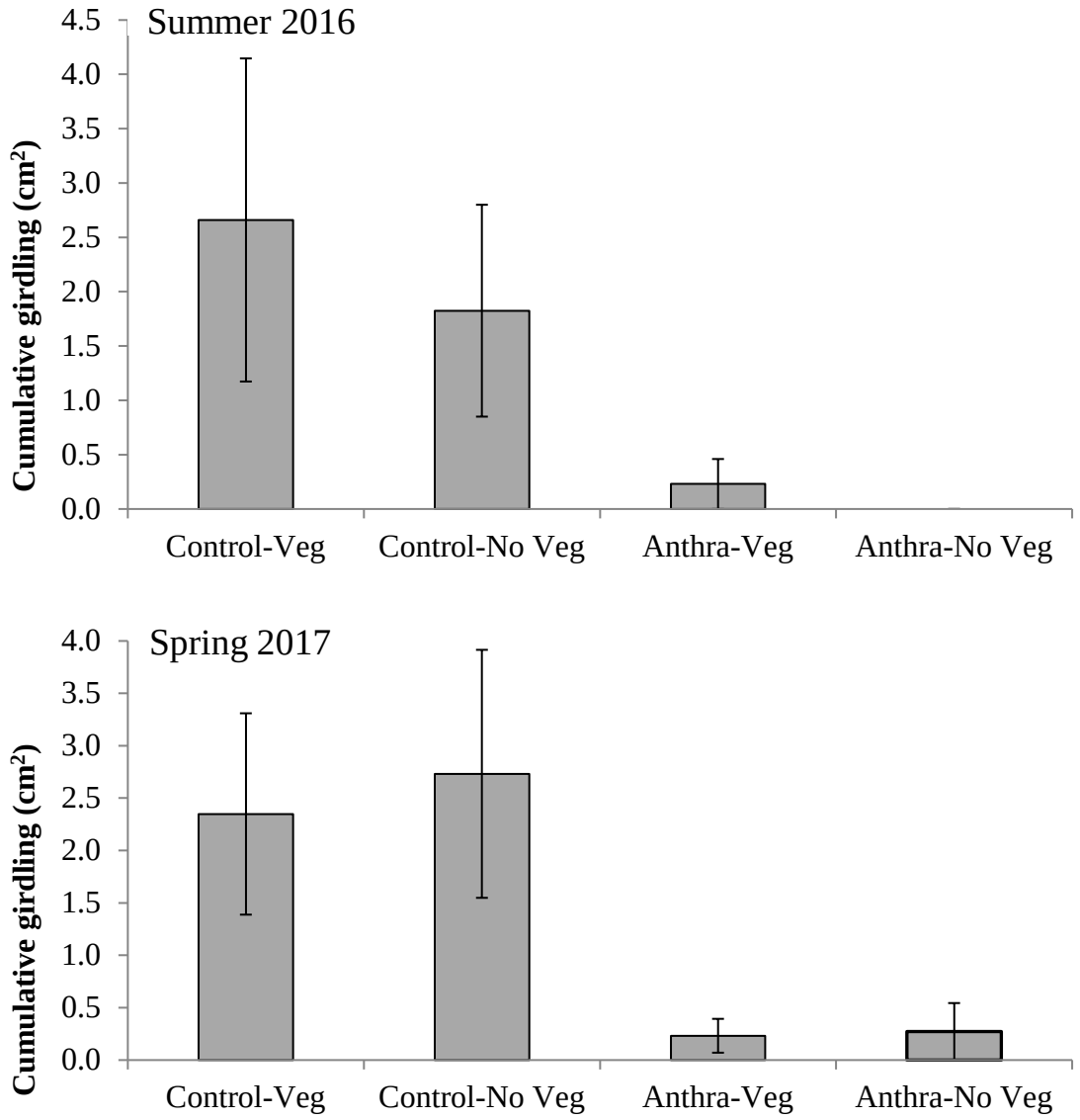

Figure 2. Mean cumulative girdling damage caused by California voles to citrus trees treated with anthraquinone (Anthra) and those trees left untreated (Control). Trees were planted in areas with (Veg) and without vegetation (No Veg) around their base. Data are provided for summer 2016 (sampling period = five weeks) and spring 2017 (sampling period = six weeks). Error bars represent standard errors.

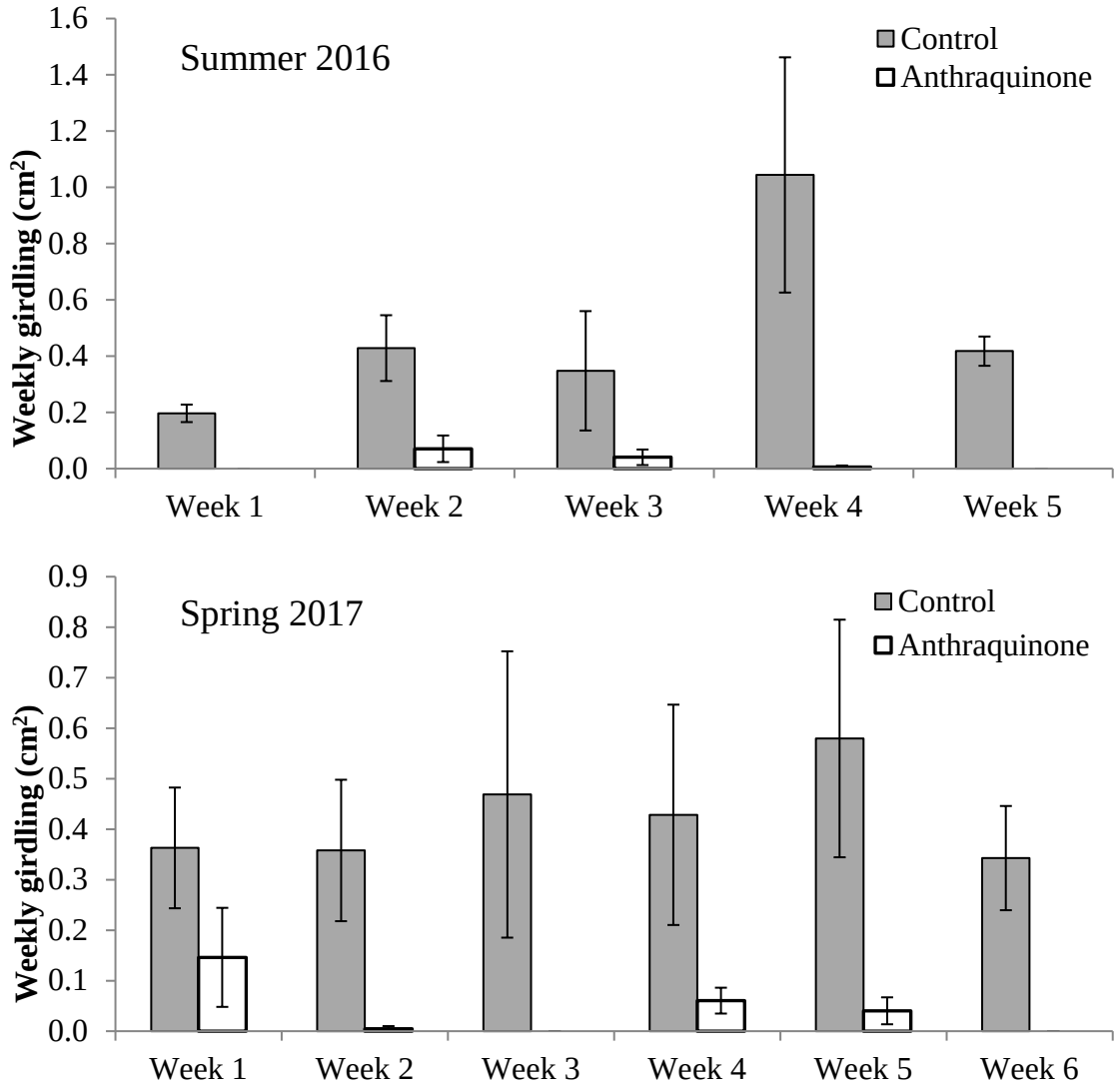

Figure 3. Temporal patterns in mean weekly girdling damage caused by California voles to citrus trees treated with anthraquinone and those trees left untreated (Control). Data illustrate potential changes in repellency over time, and are provided for summer 2016 and spring 2017. Error bars represent standard errors.

This project does not enhance the competitiveness of non-specialty crops

The University of California, Davis and the USDA National Wildlife Research Center (NWRC), developed the protocol for the vole enclosure study. Collaborators readied tub enclosures, planted trees and cover crops, captured voles and released them in tubs, applied anthraquinone treatments, and recorded data, conducted data entry, data analysis, wrote the journal manuscripts, blogs, and newsletters. USDA NWRC assisted in acquisition of anthraquinone and provided critical review of the data manuscripts. Project partners also developed the survey on grower interest in tested methodologies and analyzed results.

Goals and Outcomes Achieved

The mesocosm was established to study a design to determine the potential to use anthraquinone as a repellent combined with vegetation management to reduce vole girdling damage to citrus trees. This involved planting clementine mandarin trees and cover crops in mesocosms, and randomly selecting half of the mesocosms to receive anthraquinone treatments. Voles were then released into the mesocosms, and damage was monitored for the duration of the project to determine girdling. A survey was distributed via newsletters, blogs, and e-mail blasts that documented grower willingness to adopt these strategies into their vole IPM programs.

The positive results experienced from this project have and will continue to be disseminated for some time. Currently, there are somewhat limited on avenues for outreach given that anthraquinone is still an experimental product for use against voles (e.g., this method cannot be advocated for its use in UC IPM Pest Notes or Pest Management Guidelines until the product is registered). However, the information on the efficacy of anthraquinone and vegetation management has been provided through eight blogs and newsletters, as well as e-mail blasts sent to approximately 960 growers. Results have also been presented at five separate extension seminars/field days, reaching approximately 446 individuals. One of these extension field days included the 2017 California Specialty Crop Tour. Various regulatory personnel were present on this tour (e.g., United States Environmental Protection Agency, California Department of Pesticide Regulation). These groups expressed much interest in the project findings, which should bode well for future registration efforts.

The ultimate goal is to get anthraquinone registered for use as a vole repellent, which would reduce vole girdling damage to citrus and a number of other specialty crops. Registration of this product is a long-term outcome although substantial progress has already been made. Arkion Life Sciences is planning to pursue registration for the use of anthraquinone as a rodent repellent using data collected from this project, as well as additional data collected by USDA NWRC. The additional efficacy work will broaden the list of vole species and certify the use on citrus and other high value specialty crops across a broad geographic footprint. The filing of the label will occur once the data are reviewed later this year. The peer-reviewed publication in the *Journal of Pest Science* will be used to provide background data to support this registration.

The overall project goal was to test various concentrations of anthraquinone to determine which would be most effective at repelling vole girdling damage. However, the project team was not able to proceed with this portion of the proposed study given the inability to find good field sites for testing. As such, the project was adjusted to allow for the anthraquinone to be tested in mesocosms. With this approach, the project team tested the efficacy of a 50 percent anthraquinone solution as a vole repellent. This test was combined with a test of vegetation management to determine their combined ability to reduce vole girdling damage. As indicated in a variety of locations throughout this report, anthraquinone was highly repellent in all circumstances, whereas vegetation management was only effective at reducing vole damage during summer. An assessment of growers that would be interested in adopting the use of anthraquinone and vegetation management if proven effective was also completed. The majority that participated were interested, with 96 percent and 100 percent indicating a desire to adopt anthraquinone and vegetation management into their vole IPM programs, respectively.

The long-term outcome is to get anthraquinone registered for use against voles, which should provide growers with an effective approach to help mitigate girdling damage. However, the registration process

obviously extends well beyond the duration of this project. The shorter-term measurable outcome was to identify the willingness of local specialty crop growers to adopt the use of anthraquinone. To this end, a survey was developed and distributed through eight newsletters/blogs and two e-mail blasts to identify grower willingness to adopt the use of anthraquinone applications and vegetation management in an IPM program for vole management in appropriate specialty crops. The respondents were overwhelmingly supportive of their use with 96 percent likely to try out anthraquinone should it be registered and 100 percent of respondents willing to use vegetation management to reduce vole girdling damage. The initial goal 50 percent support, which was exceeded. Given this positive response, it is anticipated that a substantial positive impact from registration of anthraquinone as a vole repellent in citrus and other appropriate specialty crops.

Study observations showed a substantial reduction in girdling damage on anthraquinone-treated trees regardless of season (Figure 2); vegetation management further increased efficacy during the summer sampling period but had no impact in spring (Figure 2). Anthraquinone remained consistently effective for the entire duration of the project (Figure 3), indicating substantial longevity as a repellent. As such, anthraquinone appears to have substantial utility as a vole repellent. Furthermore, it was documented that a very high willingness (96 percent of respondents) of local growers to try out anthraquinone as a vole repellent should it be registered in the near future.

Beneficiaries

The primary beneficiaries from this project will be citrus, and perhaps grape and other tree fruit and nut growers. Once registered, this product would allow these growers to substantially curtail vole girdling damage in these cropping systems.

The registration of anthraquinone as a vole repellent will extend beyond the term of this project. As such, the project benchmark was to get >50 percent of growers who would use this repellent. As a result of the project efforts, it was documented 96 percent of grower respondents were interested in using anthraquinone as a vole repellent, which exceeded the initial project goals. Given how effective anthraquinone proved to be as a vole repellent, this should result in substantial economic benefit for the $1.25 billion-dollar citrus industry in California.

Lessons Learned

The overall lesson learned was that it can be challenging to find appropriate field sites for vole research projects in citrus. Voles obviously cause extensive damage in citrus, but vole populations cycle quite a bit. Most growers do not know that they are experiencing vole damage until the severe damage has occurred. By that time, the vole populations have diminished or moved out, which caused difficulty in specimen capture. This is less of a problem in other cropping systems, most notably perennial crops with lots of cover (e.g., artichokes and alfalfa). It is recommended that other researchers that wish to conduct a similar project with voles in tree or vine crops, to have seek crop sites with fairly consistent vole populations as this would greatly increase their potential success. In lieu of such consistent vole populations, the project team found that the enclosure approach with individual mesocosms was highly effective at address the project outlined goals.

The original project plan did not include the impact of vegetation management on vole girdling damage. Given shift in experimental design due to low vole populations, this management tool was able to be included. The project team was somewhat surprised that a greater impact of vegetation removal on vole

girdling damage during spring did not occur. Reasons why are unclear, but could have been due to lower temperatures that limited the need for thermal relief provided by thick and tall vegetation.

The only goal not achieved during the grant term was to test different concentration levels of anthraquinone on vole girdling damage. This was again largely due to the limitation on field sites.

Additional Information

Peer-reviewed journals, blogs, newsletters, and e-mail blasts on vole repellent:

- http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=26746
- http://calag.ucanr.edu/archive/?article=ca.2018a0030
- http://agnetwest.com/grower-input-needed-vole-management-tool/
- http://www.lodigrowers.com/got-voles-perhaps-anthraquinone-is-the-answer/
- http://www.sacvalleyorchards.com/blog/do-you-want-a-new-tool-for-vole-management/
- http://cesutter.ucanr.edu/newsletters/Pomology_Notes74539.pdf
- http://thealmonddoctor.com/2018/04/23/got-voles-perhaps-anthraquinone-answer/
- http://ucanr.edu/blogs/FoothillAg/
- https://agfax.com/2018/04/10/california-need-a-new-way-to-deal-with-voles-in-tree-and-vine-crops/

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 50	**Project Title:** Development of a rapid real time PCR assay to detect nematode pests of pistachios, walnut and almond	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB15050	**Date Submitted:** December 2018
Recipient Contact: Amanda K. Hodson	**Telephone:** (530) 752-2592	**Email:** akhodson@ucdavis.edu

Project Summary

Almond production relies on pre-plant soil fumigation to control plant parasitic nematodes and other diseases. Nematodes of concern include root knot nematode (*Meloidogyne* sp.), ring nematode (*Mesocriconema xenoplax*), and root lesion nematode (*Pratylenchus vulnus*). During feeding, these nematodes damage the root system, reducing the uptake of water and nutrients, resulting in stunted trees with reduced yield. Precisely quantifying nematode infestations requires extensive soil sampling to account for their patchy distributions. Once isolated, specialized training is also needed to correctly identify them, making quantification a lengthy and expensive process. Molecular methods of identification using real time polymerase chain reaction (qPCR) can overcome some of these drawbacks, resulting in potentially more accurate, and cost effective sample processing.

This project developed qPCR assays to detect and quantify root knot, lesion and ring nematodes from soil extracts, creating a rapid diagnostic tool that is faster and more reliable than traditional testing. qPCR assays were established to detect and quantify each species of nematode, differentiating them from other nematode genera and species. The diagnostic tool was tested on actual field samples and compared to traditional microscopic methods in cooperative extension field trials and grower orchards. The project staff attempted to relate nematode populations in existing management trials with tree growth to see if the diagnostic method more accurately predicts nematode damage than traditional methods.

Accurate surveillance of nematode pests is essential to effective management. Plant parasitic nematodes can increase exponentially after orchard establishment, stunting the roots of young trees and predisposing the tree to other disease, such as bacterial canker. Currently tree crops are routinely fumigated pre-planting to control root knot, lesion and ring nematodes but the use of these chemicals is increasingly restricted, and growers are experiencing more pressure to reduce fumigant applications whenever possible. Treatment recommendations sometimes cite the presence of only one nematode as cause for action, but actual economic thresholds are unknown, and treatment is largely a matter of risk management. As soil fumigants become less available, though, the ability to determine whether nematodes are present and how much damage they are causing becomes more critical.

This project developed and field tested a rapid nematode diagnostic tool that can simultaneously identify and detect root knot, lesion and ring nematodes from soil extracts. Two diagnostic laboratories are currently interested in adopting the method and protocols and methods have been shared as well as technical expertise on how these labs offer the assay to growers, markedly enhancing the speed and reliability of nematode detection in tree crops.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Objective 1 Establish the diagnostic method:

Before experiments could begin, cultures were established in the laboratory of each species of nematode. These cultures were sterile except for the nematode and the plant involved, making it possible to troubleshoot any problems having to do with the specificity of the assay aside from other factors that could influence it in a more complex soil environment. The technician and professional researcher then designed qPCR primers that accurately identified each species. Primers were designed using the 28S rRNA gene for *P. vulnus* and 16S gene for *M. xenoplax* based on annealing temperature and guanine-cytosine (GC) content. For root knot nematode, previously developed primers were used. Specificity was initially assessed by screening nematode sequences stored in GenBank via BLAST. These primers were then evaluated for specificity against each other and nematodes kept in tissue cultures (Table 1). A reference set of primers was used to confirm that DNA extractions were successful, and that non-detection was due to primer specificity. These experiments showed that the primers were highly specific and that off-target amplification was undetectable in the higher Ct (less DNA) ranges. Standard curves were constructed of known nematode numbers and the cycle threshold (Ct) value for each species. These standard curves were then used to predict the number of nematodes in samples spiked with known numbers in the laboratory (Figure 1).

Species	qPCR Assay (PC18 primers)	qPCR Assay (MX28 primers)
Pratylenchus vulnus	21.2 *	32.5
Mesocriconema xenoplax	36.7	21.3 *
Meloidogyne incognita (race 3)	32.5	36.3
Xiphinema index	28.8	31.5
Xiphinema americanum	32.7	29.7

Table 1. Nematode populations used to test the specificity of the lesion nematode primers (PC18) and ring nematode primers (MX28) * Indicates more than a 100 fold binding specificity to intended target compared to off target species.

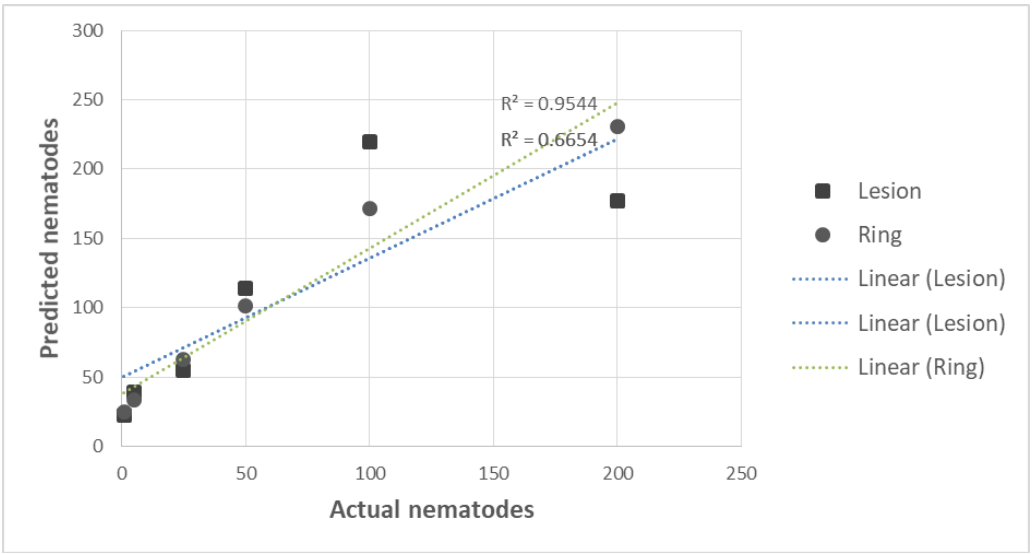

Figure 1. Relationship between known nematodes added to solution and nematode numbers predicted using the currently developed qPCR assay.

Objective 2: Compare molecular based sampling to traditional methods:
During the fall of each year, the University of California (UC) Davis team and farm advisor cooperators travelled to preexisting cooperative extension field trials in Bakersfield and Madera, California and sampled soil from fumigated and unfumigated blocks to ensure a range of nematodes. Over 200 samples were evaluated over the course of the project from six different orchards using both qPCR and traditional microscopy. For field tests, nematodes were extracted from 200 milliliter (mL) soil via sugar centrifugation and concentrated into a 4 mL solution. The sample was vortexed for five seconds to mix nematodes and water thoroughly, then a glass pipette was used to load 2 mL of liquid/nematodes onto plastic slide with a 1 mL field of view. The other 2 mL of solution remaining was further concentrated to 0.5 mL and transferred to a DNeasy PowerSoil tube for DNA analysis. Real time PCR reactions for each soil sample were run in triplicate with positive and negative controls on each 96 well plate.

The relationship between the microscopic counts of nematodes and the nematodes predicted by the molecular assay varied greatly between sites. This likely was due to soil factors, such as organic matter, which can inhibit DNA extraction. Multiple experiments were conducted to determine what sources of error were causing variability between the two methods. Physical measures were taken to ensure that no nematodes were being lost during transfer to the DNA extraction tube. Methods were also designed that were able to detect and correct for the degree of DNA inhibition in the soil extracts. For example, DNA from green fluorescent protein (eGFP) was spiked into samples to act as a standard. The extraction efficiency was calculated by dividing the known number of spiked DNA copies by that predicted by the molecular assay. Then the number of nematodes predicted by the nematode standard curve was corrected for the DNA extraction efficiency of the GFP protein in that sample. This resulted in somewhat more accurate predictions. To further reduce variation in field predictions, a reducing agent, β-mercaptoethanol (BME), was added prior to DNA extraction. Once these measures were taken, the assay predicted nematode counts well in soil extracts (Figure 2).

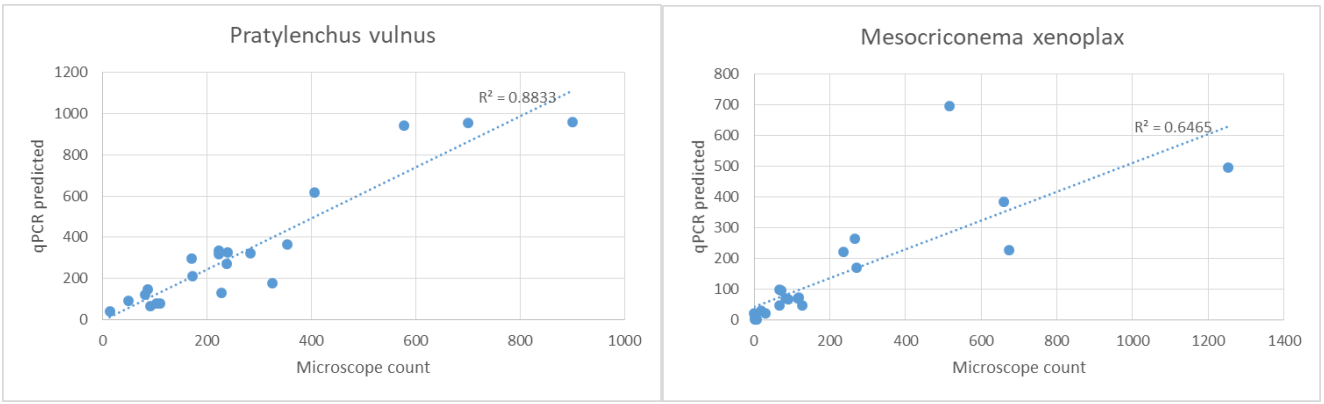

Figure 2. Relationships between microscopic counts of nematodes and that predicted by a qPCR assay for lesion nematode (Pratylenchus vulnus) and ring nematode (Mesocriconema xenoplax). Samples were collected from a walnut orchard in Winters, California in Spring of 2018.

Objective 3: Determine nematode populations associated with damage
Measurements of trunk diameter that were taken each year (a proxy for tree size) were related to nematode counts evaluated both microscopically and by qPCR. No consistent relationship was observed between trunk diameter and nematode numbers quantified by either method. This could be due to the fact that samples came

from cooperative extension trials evaluating different nematicides, and some of these products are known to allow trees to tolerate higher numbers of nematodes with less effects on growth and yield. The trees samples were also 5-12 years old and nematode infestation might be expected to have the greatest impact on growth early in the trees life, a period which was not measured in during this grant.

Objective 1-3: Deliver outcomes on full scope of the project:
Throughout the project, the researcher consulted with representatives from industry, commodity boards and farm advisors to gather their perspectives and integrate them into scientific conclusions. This included optimizing the methods to be as cost effective as possible (choosing a Sybr green assay instead of a more expensive Taqman one) but also changing plans for outreach and implementation of the diagnostic assay. Multiple stakeholders pointed out that presenting the results of the assay to growers in a field day would probably not result in adoption, since growers lack the technology to perform the diagnostic tests themselves. Therefore, instead of field days, the diagnostic assay, data and methodology was presented in workshops with two individual diagnostic labs that would like to offer the molecular assay to growers commercially. Presentations and sharing of protocols occurred with AL&L Crop Solutions (Vacaville, California) on December 1, 2017 and June 30, 2018 as well as with representatives of TriCal Inc. (Hollister, California) on May 30 and June 24, 2018.

Presentations were also made locally to growers, farm advisors, and students to raise awareness of the new method. The researcher shared results of the project in a talk to approximately 100 growers, farm advisors and industry representatives at the 38th international Carrot Conference in Bakersfield, California on March 20, 2017. The researcher also gave a poster presentation on December 7, 2017 at the Almond Board of California's almond conference in Sacramento, California entitled 'Development of a rapid real time PCR assay to detect nematode pests.' The researcher also gave a talk to farm advisors with the same title on December 8, 2017 at the Almond Workgroup Meeting of UC Cooperative Extension personnel in Davis, California. Other talks included presentations to about 30 students in the UC Davis classes 'Sustainability and Agroecosystem Management' and 'Introduction to Plant Breeding.'

This project did not benefit commodities other than specialty crops.

Farm advisor from Merced County, California provided access to almond and pistachio field sites and assistance with sampling. Almond and walnut growers provided access to orchard for sampling. Farm advisor from Stanislaus County, California provided access to almond field sites and assistance with sampling. Cooperative Extension Specialist from UC Davis. Provided access to walnut field sites.

Goals and Outcomes Achieved

Outcome 1: Increase capability to detect and quantify root knot, lesion and ring nematodes by developing qPCR assays:
The method has been developed and optimized and all the protocols have been finalized. In field samples and in the laboratory, it is able to detect all target species at both high densities (over 1,000 nematodes) and low densities (1/10 nematode).

Outcome 2: Increase knowledge of the efficacy of these assays by comparing results to those obtained by traditional microscopy:

The diagnostic method is able to accurately predict the number of nematodes extracted from soil samples, relating well to microscopic counts with an R^2 of 0.88 for lesion nematode and 0.65 for ring nematode. While predictions for root knot nematode functioned well in the laboratory, few samples collected in the second year had detectable levels of this species, so that knowledge of the assays efficacy is not as well established.

Outcome 3: Increase knowledge of what level of nematode populations are damaging to orchards by relating nematode numbers to aboveground crop growth:
Regression relationships were performed between trunk diameter and lesion and ring nematode numbers. No strong relationships were observed between nematode numbers and trunk diameter. This likely reflected the age of the orchard and other variability in tree size. This outcome was largely not completed since there were no strong relationships observed between nematode numbers and trunk diameter. To accurately model the number of nematodes that are damaging to orchards, it appears that trees would have needed to have been monitored from the time of planting.

Outcome 1-3: Deliver outcomes on full scope of the project:
The molecular assay (including protocols, primers and techniques) were shared through workshops with two diagnostic laboratories. These laboratories are very interested in offering the method to growers as part of their ongoing services making it likely that the molecular assay will be available to growers soon.

For outcome 1, the assay was able to detect nematodes at concentrations as low as 1/10 nematode in solution. If even one nematode was present in a solution for counting under the microscope, it is likely it would be missed during transfer or through misidentification. Therefore, the molecular assay theoretically increased the ability to detect pest nematodes in soil solutions by a factor of at least 10. For outcome 2, the accuracy of the assay consistently improved with optimization in the laboratory. While the relationship between microscopic counts of nematodes and molecular predictions was initially very low (at 10 percent accuracy), it continuously increased with optimization, reaching 65 percent accuracy for ring nematode and 88 percent for lesion.

A molecular assay was designed which detects and quantifies three species of pest nematodes in orchards. The assay was optimized and found to relate well to microscopic counts of nematodes in solution. Variability in the assay's effectiveness was addressed by designing checks to account for variability in extraction efficiency between soil types. The protocols for the molecular assay were shared with two diagnostic laboratories that plan to offer the assay in the future and results of the project were shared with over 200 stakeholders.

Beneficiaries

The California pistachio, almond and walnut industries are the direct beneficiaries of this research. To manage nematode pests effectively, accurate surveillance is essential to effective management. Currently tree crops are routinely fumigated pre-planting to control root knot, lesion and ring nematodes but the use of these chemicals is increasingly restricted, and growers are experiencing more pressure to reduce fumigant applications whenever possible. As soil fumigants become less available, the ability to determine whether nematodes are present and how much damage they are causing becomes more critical. This project developed and field tested a diagnostic tool to detect and quantify two of the main nematode pests of tree crop production, markedly enhancing the speed and reliability of nematode detection. A more accurate representation of field infestation rates will benefit growers and the public by preventing un-needed pesticide applications, which are economically costly to the pistachio, walnut and almond industries, as well

environmentally costly, since soil fumigants used in tree crop production present high risk to the safety and health of workers, bystanders, and wildlife.

If the cost of nematode testing is reduced, then growers will be able to sample their land more accurately, and thus will be able to make better pre-plant decisions. For example, the sensitivity of the molecular assay can give assurance that when no nematodes are detected pesticide applications may be unnecessary saving up to $1,000 per acre. By collaborating and sharing protocols with two diagnostic laboratories that routinely process large numbers of samples, the project could benefit more than 500 growers of tree crops in California.

Lessons Learned

One main lesson learned by project staff was that it was easier to extract nematodes from soil solutions rather than directly from dry soil as originally proposed. For dry soil, the sample size of many DNA extraction kits was too small to provide a meaningful reference for soil samples collected over a large area. When nematode infested soil was dried and ground, no nematode DNA was detected. Since methods were already in place in the lab to extract nematodes from soil into solution, and this method has also been shown to reduce inhibitors in the soil which inhibit DNA extraction, UC Davis staff were able to successfully use this method to create a concentrated solution of nematodes which resulted in good enough quality to be used in qPCR reactions.

Another lesson learned was that nematode damage is best quantified on a fine root scale or on younger trees where differences in growth is more obvious. The project had initially planned to use a root viewing camera (the minirhizotron) to monitor growth of new roots over time and relate to nematode numbers, but this broke due to electrical problems from years of wear and tear. Since the cost to repair the root camera was prohibitive, we instead replaced this method with other measures of tree productivity such as stem diameter. In order to understand what levels of nematodes are damaging to tree growth, longer term studies would be needed, or experiments with small, recently planted trees. Since the trees measured in this project were already large and mature, many other factors other than nematodes likely influenced their development.

It was more difficult to optimize the assay for field samples than expected. While the assay performed well on pure cultures of nematodes from the laboratory, at first it did not predict microscopic counts of nematodes well on soil samples from the pistachio and almond orchard locations. Most likely these differences were due to different soil types which can present obstacles to DNA extraction and primer efficacy.

Experiments were conducted to account for variation in the assay's accuracy with some success. While spiking the DNA extracts with a known number of "reference nematodes" did not improve the predictions, spiking with a known quantity of DNA (eGFP) and correcting for extraction efficiency did to some extent. Finally, the addition of a reducing agent before DNA extraction (BME) reduced the inhibition enough that the assay accurately predicted what nematodes were seen under the microscope.

One outcome measure that was not completely accomplished was: Increasing knowledge of what level of nematode populations were damaging to orchards by relating nematode numbers to aboveground crop growth. Data was collected on trunk diameter and statistical models run to see if nematode numbers (either quantified by microscopic counts and molecular assay) predicted trunk diameter, however; no strong relationship was found. For future studies, in order to understand what levels of nematodes are damaging to tree growth, experiments with small, recently planted trees would be needed, with these trees tracked for growth and productivity over a period of years.

Additional Information

Data on pest nematodes collected from the project resulted in a pending manuscript which is still being worked on and will be submitted to the Journal of Nematology sometime in the Spring of 2019.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 51	**Project Title:** New Lettuce Cultivars with Resistance to Lettuce Drop	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB15051	**Date Submitted:** December 2018
Recipient Contact: Krishna V. Subbarao	**Telephone:** (831) 755-2890	**Email:** kvsubbarao@ucdavis.edu

Project Summary

Lettuce drop (LD) is an economically important soil borne disease of lettuce. It is caused by the fungal pathogens *Sclerotinia minor* (*S. minor*) and *Sclerotinia sclerotiorum* (*S. sclerotiorum*) resulting in decay of the crown tissue, wilting of leaves and total collapse of the entire plant before harvest. The use of genetic resistance as part of an integrated LD management strategy would provide a sustainable approach to reducing loss of produce. LD resistance is often associated with traits related to plant development, primarily rapid bolting. Due to this reason, LD resistance identified in the past could not be used in breeding of modern lettuce cultivars. Recently, high level of resistance to *S. minor* and *S. sclerotiorum* independent of plant morphology that is genetically determined was identified in the slow-bolting red Latin type cultivar, Eruption. Eruption is unsuitable for widespread production, but its resistance can be bred into popular lettuce types. To use the resistance in Eruption for breeding, understanding the genetic basis of resistance is essential. The overall objective of this project was to increase the number of resistant cultivars for which, information on the inheritance of resistance was needed. Eight resistant romaine breeding lines have already been developed. Therefore, the first objective to fully characterize the yield and adaptation of these lines to identify the ones worthy of public release was accomplished. A recombinant inbred line (RIL) population also was developed from a cross of Eruption to the susceptible cultivar Batavia Reine des Glaces (BRG). The RIL population totaling 162 was self-pollinated to the F_8 generation. The second objective was to evaluate the RIL population for resistance and plant morphology to determine the inheritance of LD resistance in Eruption, map its genetic basis and characterize the relationship to those that underlie rapid bolting.

Fungicides and cultural methods have traditionally been used for LD control. However, these methods do not reduce LD to satisfactory levels. In addition to their adverse effects on the environment and human health, repeated applications of fungicides also are associated with the risk of fungicide-resistance development in the pathogen population. Therefore, the most practical mechanism of LD control should involve the use of an integrated disease management strategy. Host resistance is the most convenient, sustainable, and environmentally friendly component to incorporate into an integrated scheme for controlling LD.

Given the economic impact of LD and the limitations of alternative control methods, several attempts were made to identify lettuce genotypes with resistance to the disease for over 40 years. Partial resistance to LD was observed in lettuce cultivars, primitive forms and its wild relatives through previous research. Resistance in these cases was often associated with traits related to plant development; including rapid bolting, low leaf area, and upright growth habit – all unwanted traits in modern lettuce cultivars. Thus, the identification of resistance in Eruption is significant. This project was important and timely as genetic characterization of LD resistance in Eruption is a prerequisite to efficiently transfer the resistance into commercial-quality lettuce genotypes.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The following is a list of activities and tasks that were performed during the entire grant period:

1. Production of *S. minor* sclerotia for 2016 and 2017 lettuce drop resistance screening field experiments.
2. Experiment Imperial Valley (IV): Evaluation of eight breeding lines, and control cultivars (Tall Guzmaine, Green Forest, Braveheart, and Green Towers) in IV field experiments. Collection of data on yield, head weight, core height, head closure, and percent tipburn.
3. Experiment Salinas Valley (SV): Evaluation of eight breeding lines in SV field experiments to assess the shelf-life of processed salad and whole heads.
4. Compiling and analyzing breeding lines data, release germplasm.
5. Experiment LD for three seasons: evaluation of 162 RILs from BRG x Eruption and their parents for LD incidence in field experiments artificially infested with *S. minor* at the United States Department of Agriculture (USDA), Salinas research station.
6. Experiment Plant Morphology (PM): Evaluation of 162 RILs from BRG x Eruption and their parents for bolting in the LD field experiments at the USDA, Salinas Research Station.
7. Tissue collection, DNA extraction and genotyping of 162 RILs from BRG x Eruption. Generation of single nucleotide polymorphism (SNP) data.
8. Construction of genetic map using SNP data.
9. Mapping quantitative trait loci (QTL) using the disease incidence and the genetic map datasets.
10. Outreach: Communicate results at biennial meetings of the California Leafy Greens Research Board (CLGRB) and the annual meetings of either the American Society for Horticultural Science (ASHS) or the American Phytopathological Society (APS).
11. Write and publish manuscripts.

Greater than 40 kg of *S. minor* sclerotia were produced for use in three infested LD field experiments (in 2016 and 2017) at the USDA, Salinas Research Station. Seed of each RIL and parents were increased in a central valley field. This provided sufficient seed for all experiments conducted.

This project had both breeding and genetics components. The breeding part of the project was to develop and distribute improved lines of lettuce that have LD resistance. Multiple field experiments were conducted in the low desert, IV using experimental Hearts Delight x Eruption romaine breeding lines to evaluate for yield and horticultural characteristics. The breeding lines were consistently too small to be commercially viable in these environments. They demonstrated problems with fringe burn and short shelf life as salad-cut lettuce. Based on the testing that has already been completed, it is clear that these lines are not suitable for commercial use. As such, it was decided not to test the lines in additional field experiments.

The experimental Hearts Delight x Eruption crosses were made to introgress quantitative resistance loci (QRL) to LD from ‘Eruption’ to romaine type lettuces. More than 32 romaine breeding lines were tested in the SV experiments for yield, horticultural characteristics and shelf-life of processed salad and whole heads. Eight breeding lines were selected and evaluated in multiple field experiments at a USDA field plot in Spence near Salinas, California. Data was collected on yield, head weight, core height, head closure, percent tipburn, shelf-life of processed salad and whole heads. The eight breeding lines selected have improved resistance to LD compared to Hearts Delight but less than ‘Eruption’. The lines were also tested for resistance to downy mildew, and impatiens necrotic spot virus. In terms of horticultural traits, the lines are similar to Hearts

Delight in shelf-life, height, weight, core length, maturity and tipburn incidence. Data of the breeding lines have been compiled and analyzed. The target is to release at least one LD resistant and high yielding romaine breeding line. A release notice is being prepared and will be released to the public in 2019. After the release notice is published, project staff will send out a statement to the seed companies and the CLGRB inviting them to request small quantities of seeds from the project.

The genetics part of the project focused on studying the inheritance of LD resistance, mapping its genetic basis and relationship with bolting. The 162 RIL population was used to accomplish these objectives. The RIL population and parents were evaluated for LD incidence and bolting in a field artificially infested with *S. minor* at the USDA, Salinas Research Station in three seasons (in 2016 and 2017). The LD datasets from the three experiments had good positive correlation (Table 1). In other words, RILs with low disease incidence had a similar low disease levels in all the three experiments and vice versa. On the other hand, as suspected, LD and bolting were negatively associated (Table 1), indicating that fast bolting lines had relatively lower disease incidence. Consistent with the initial observation, the two parents exhibited a distinct level of LD incidence. The RIL population showed a continuous phenotypic variation in response to LD (Figure 1). The population had disease rating scores that ranged from 0.53 to 1.45, with a mean of 1.07 in Spring 2016 (Figure 1A). In Fall 2016, the RILs had diseases ratings ranging from 0.29 to 1.30 with a mean of 0.86 (Figure 1B). The rating scores ranged from 0.45 to 1.21, with a mean of 0.85 in Spring 2017 (Figure 1C). These phenotypic distributions in the mapping population are typical of quantitative traits, indicating that Eruption has quantitatively inherited resistance loci against LD.

Table 1. Correlation coefficients for LD disease incidence and rate of bolting in the BRGlaces x Eruption recombinant inbred lines evaluated in three experiments (LD16.1, LD16.2 and LD17.1) in Salinas, California, in 2016 and 2017.

Phenotype	Drop LD16.1	Drop LD16.2	Drop LD17.1	Bolting LD16.1	Bolting LD16.2	Bolting LD17.1
Drop incidence (LD16.1)	1					
Drop incidence (LD16.2)	0.589	1				
Drop incidence (LD17.1)	0.589	0.650	1			
Rate of bolting (LD16.1)	-0.298	-0.256	-0.325	1		
Rate of bolting (LD16.2)	-0.294	-0.246	-0.260	0.668	1	
Rate of bolting (LD17.1)	-0.243	-0.286	-0.269	0.697	0.634	1

Correlation coefficients > 0.255 (in absolute values) are significant at $p < 0.001$; coefficients 0.209 to 0.255 (in absolute values) are significant at $p < 0.01$.

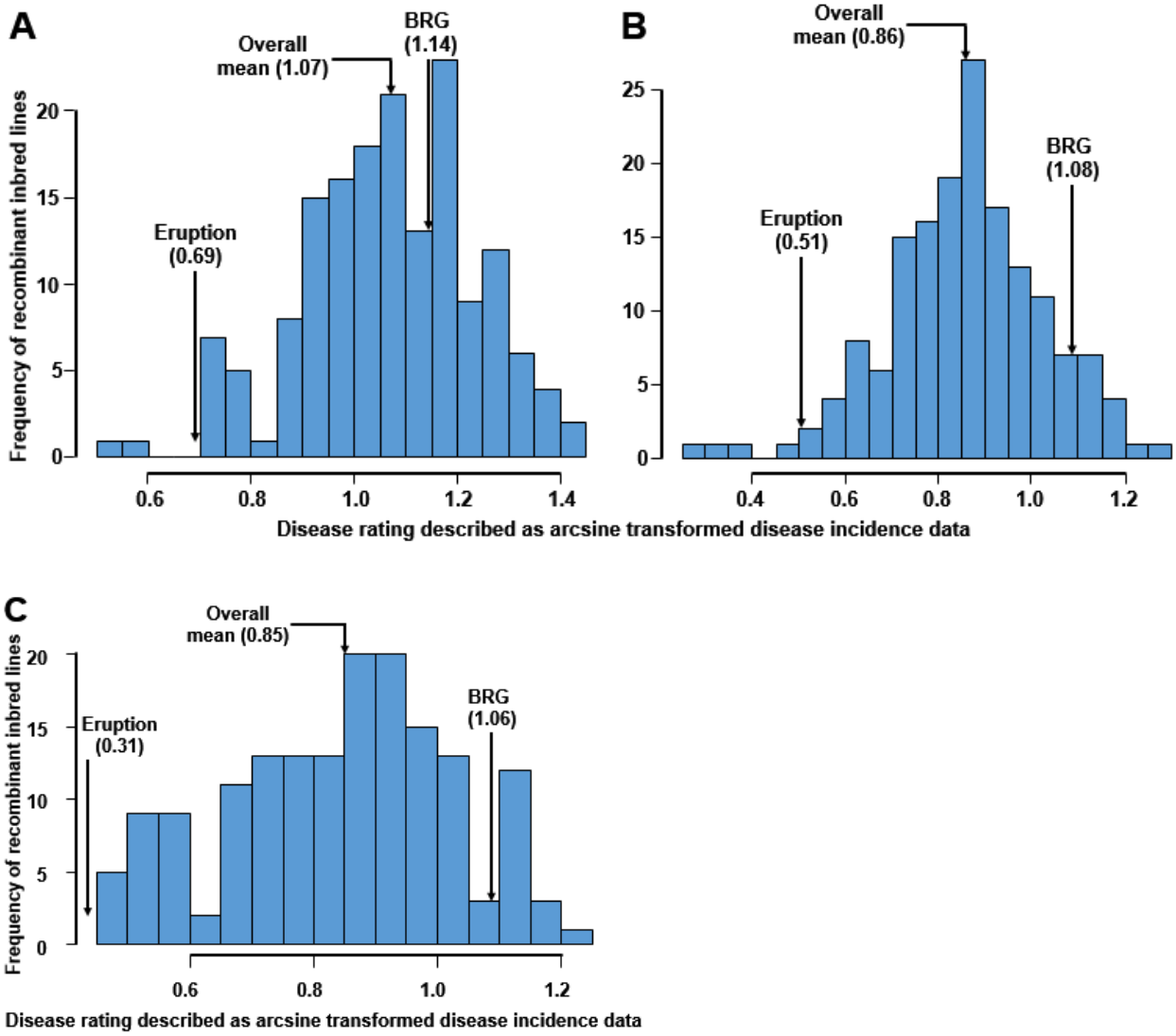

Figure 1. Distribution of 'disease rating' of BRGlaces x Eruption recombinant inbred lines and parents in *S. minor*-infested field experiment (A) Spring 2016, (B) Fall 2016, and (C) Spring 2017

To determine the genetic basis of resistance, it was important to develop genetic markers. SNP markers were developed via genotyping-by-sequencing (GBS). Tissue was collected from the 162 RIL population and parents, DNA extracted, and subjected to GBS. The GBS analysis identified 840 SNPs. Genetic map was constructed using the SNP data. The SNP markers mapped to the nine linkage groups of lettuce with a good coverage (Figure 2).

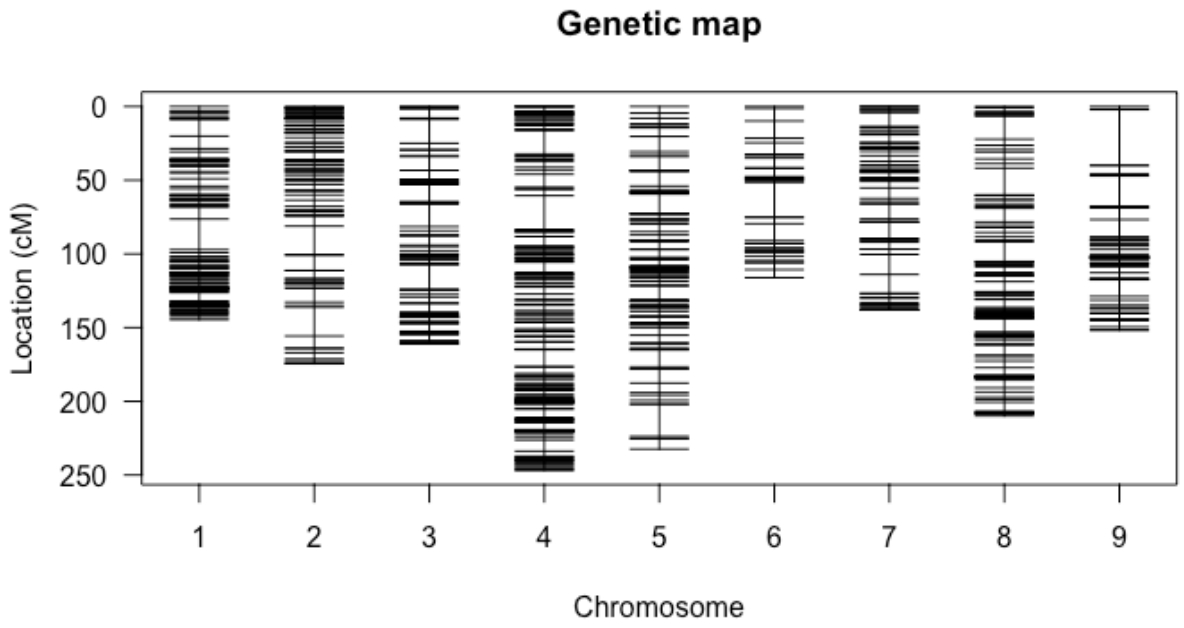

Figure 2. Illustration of 840 single nucleotide polymorphism markers along the nine linkage groups of lettuce. Individual SNP markers are represented by a single horizontal line (marker not shown for brevity).

Mapping the genetic basis of LD resistance and determining its relationship with bolting required associating the genetic map information with disease and bolting data obtained from the field experiments through QTL mapping. The QTL mapping analysis indicated that at least two genes with small effects are responsible for LD resistance in Eruption. The genes are located on lettuce chromosomes one and five (Figure 3) and explain the 9-12 percent and 11-25 percent of the variation in LD, respectively (30-41 percent total). Two additional QTL were also identified on chromosomes four and seven (Figure 3), explaining roughly 9 percent and 11 percent of the variation in LD, respectively.

As indicated above, LD and rate of bolting were negatively associated, confirming that fast bolting lines had relatively lower disease incidence. However, the LD resistance at the QTL on chromosomes one and five were independent of bolting. Likewise, the two other LD resistance QTL on chromosomes four and seven were located where no bolting QTL was identified (Figure 3), indicating that bolting has little effect on drop resistance in these genomic regions. Eruption is dark red in color due to anthocyanin pigmentation. Genetic analysis identified a gene underlying anthocyanin content at a different location from resistance QTL on chromosome five (Figure 3), indicating that LD resistance is not associated with anthocyanin pigmentation in Eruption. Thus, Eruption could be used in developing both green and red lettuce types with LD resistance.

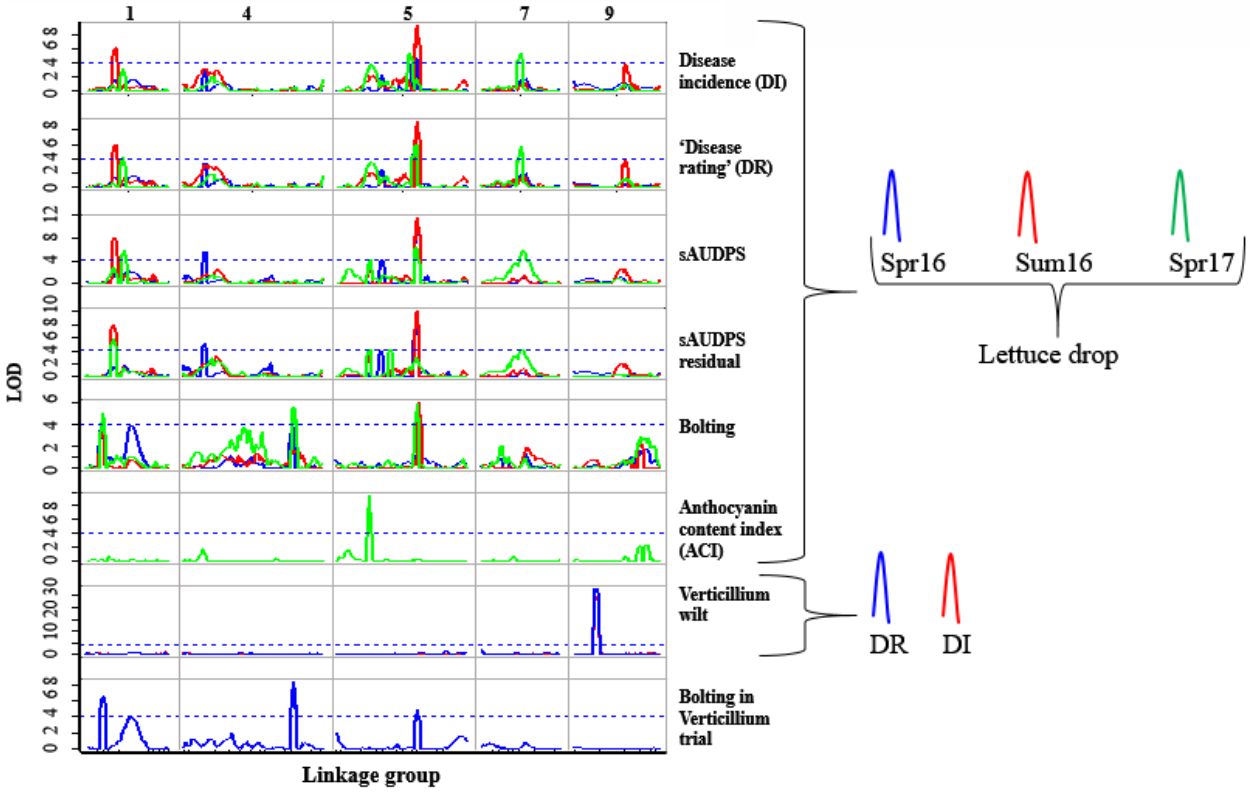

Figure 3. Quantitative trait loci (QTL) on linkage groups 1, 4, 5, 7 and 9 for LD resistance, rate of bolting, anthocyanin content index (ACI) and Verticillium wilt resistance identified in the Batavia Reine des Glaces x Eruption recombinant inbred lines. The blue horizontal dashed line corresponds to significant thresholds.

In addition to LD, Eruption has complete (100 percent) resistance against another major soilborne disease of lettuce called Verticillium wilt. Verticillium wilt is caused by two different races of the fungal pathogen *Verticillium dahliae*. Eruption is resistant to race one. This is significant as it is unusual to find lettuce genotypes resistant against two soilborne pathogens (along with LD caused by *Sclerotinia species*). Like for LD, identifying the gene(s) and liked molecular markers is important to develop breeding lines that are resistant to Verticillium wilt and transferring this resistance to commercial cultivars. To this effect, a replica of the 162 RILs also were evaluated during the spring-summer 2017 experimental season in a field infested with race one of *V. dahliae*. Verticillium wilt incidence data was recorded at harvest maturity. Analysis of the disease data, after converting to 'disease rating', indicated the existence of phenotypic variation in the RIL population (Figure 4). The distribution of the phenotype data indicated that Eruption likely has one major resistance gene against race one of *V. dahliae*. Eruption had a disease incidence/rating of 0. Whereas, BRG, the susceptible parent, exhibited a rating score of 0.72. For the RIL population, the disease rating scores ranged from 0 to 1.15 with a mean of 0.41.

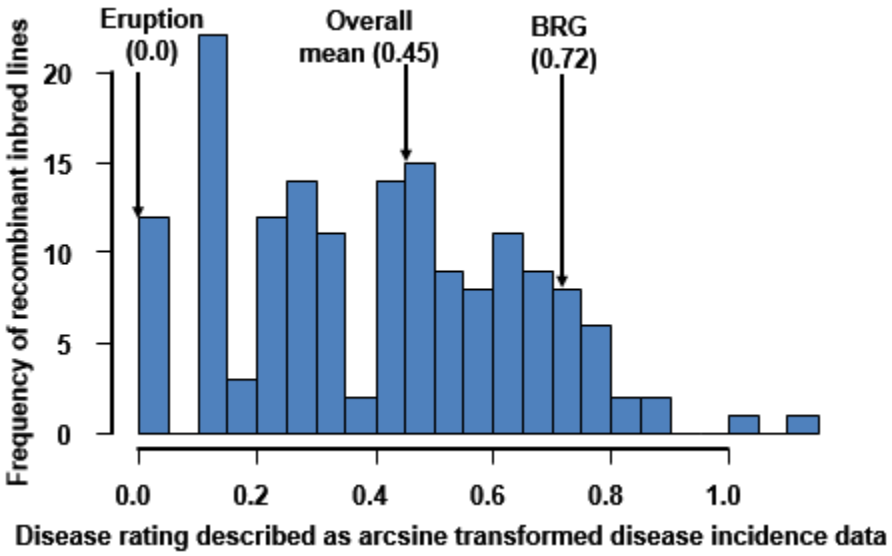

Figure 4. Distribution of 'disease rating' of Batavia Reine des Glaces x Eruption recombinant inbred lines and parents in a field experiment infested with race one of Verticillium wilt (spring-summer 2017)

QTL mapping identified one genomic region on chromosome nine, explaining 47–51 percent of the variation in Verticillium wilt (Figure 3). This genomic region of chromosome nine was previously identified to have the *Vr1* (*Verticillium resistance 1*) gene, and the gene in Eruption appears to be the same. Additional tests of the most resistant and the most susceptible RILs from the population with molecular markers (developed by another project) confirmed that *Vr1* is responsible for race 1 resistance in Eruption. Genetic markers identified would be useful in marker-assisted transfer of lettuce drop and Verticillium wilt resistance from Eruption to commercial lettuce cultivars.

Preliminary results of the project were presented at the CLGRB annual research conference on March 14, 2017 in Pismo Beach, California. The meeting was attended by about 150 people from the industry, growers, pest control advisors and lettuce scientists from the USDA and the academics in California. In addition, a poster titled "Genetic characterization of resistance to *Sclerotinia* in lettuce cultivar Eruption" was presented at the 2017 APS annual meeting held August 5-9 in San Antonio, Texas. The poster attracted the interest of a large number of people both from the industry and academia. Some of those who stopped by the booth took a printed copy of the poster or took pictures of the poster. A couple of them made a request, at the meeting or thereafter, for seed or detailed information regarding the QTL identified. Project summary was also presented at the CLGRB mid-year meeting on October 10, 2017. Summary of results from breeding activities (in general) and the genetics part of the project (both on LD and Verticillium wilt) were also disseminated at the CLGRB annual research conference on March 27, 2018 in Pismo Beach, California.

Project data have been compiled and analyzed. Results have been summarized and a manuscript has been prepared to formally communicate this knowledge to lettuce breeders through a peer-reviewed publication. Information on the breeding lines of romaine lettuce developed with improved resistance to LD will also be released to the public. The release notice and the manuscript will be published in 2019.

This project solely enhanced the competitiveness of specialty crops, specifically lettuce.

The GBS of the BRG x Eruption population was carried out by the research group at the University of California, Davis Genome Center. This is a significant contribution to the project in the sense that genotype information generated was a foundational resource for QTL analysis – in association with the phenotype date collected from field evaluations. An autoclave at the USDA was extensively utilized to autoclave hundreds of pounds of cut potato to produce sclerotial inoculum of *S. minor* to use for artificial infestation of the repeated field experiments. This enabled field evaluation of breeding materials since the project started. A USDA field plot that has been used to screen lettuce breeding material for the past 10 years is being used for this project to evaluate the breeding material for resistance against the pathogen. A field pilot that USDA has dedicated for screening of breeding materials for race one of Verticillium wilt was utilized for evaluation of the breeding materials.

Goals and Outcomes Achieved

Goal 1: Increase the number of publicly available romaine breeding lines with LD resistance.
Target: Publicly release at least one resistant and high yielding romaine breeding line adapted to a California production district.
Activities Completed to achieve this goal and measurable outcome:

- Sclerotia of *S. minor* produced for the 2016 and 2017 LD resistance screening field experiments.
- Experiment IV: Evaluation of eight breeding lines, and control cultivars (Tall Guzmaine, Green Forest, Braveheart, and Green Towers) in IV field experiments. Collection of data on yield, head weight, core height, head closure, and percent tipburn.
- Experiment SV: Evaluation of eight breeding lines, and controls in SV field experiments to assess the shelf-life of processed salad and whole heads.
- Experiment LD for three seasons: Evaluation of eight breeding lines, and controls for LD incidence in field experiments artificially infested with *S. minor* at the USDA, Salinas Research Station.
- Outreach: Results communicated at biennial meetings of the CLGRB (in 2017 and 2018).
- Breeding line data compiled and analyzed; germplasm release notice in preparation.

Goal 2: Generate new knowledge on the inheritance of LD resistance in Eruption and communicate this knowledge to lettuce breeders.
Target: Submit at least one manuscript reporting the number and location of resistance QTL in Eruption.
Activities Completed to achieve this goal and measurable outcome:

- Sclerotia of *S. minor* produced for the 2016 and 2017 LD resistance screening field experiments.
- Experiment LD for three seasons: Evaluation of 162 RILs from BRG x Eruption and their parents for LD incidence in field experiments artificially infested with *S. minor* at the USDA, Salinas Research Station.
- Experiment PM: Evaluation of 162 RILs from BRG x Eruption and their parents for bolting in the LD field experiments at the USDA, Salinas Research Station.
- Tissue collection, DNA extraction and genotyping of 162 RILs from BRG x Eruption. Generation of SNP data.
- Construction of genetic map using SNP data.
- Mapping QTLs using the disease incidence and the genetic map datasets.
- Outreach: Results communicated at biennial meeting of the CLGRB (in March 207 and 2018) and the 2017 APS Annual Meeting.
- Publication of manuscript is expected to be released in 2019.

Goal 3: Increase the number of seed companies conducting LD resistance breeding.
Target: Increase the number of companies conducting LD resistance breeding to more than five.
Activities Completed to achieve this goal and measurable outcome:

- Sclerotia of *S. minor* produced for the 2016 and 2017 LD resistance screening field experiments.
- Experiment IV: Evaluation of eight breeding lines, and control cultivars (Tall Guzmaine, Green Forest, Braveheart, and Green Towers) in IV field experiments. Collection of data on yield, head weight, core height, head closure, and percent tipburn.
- Experiment SV: Evaluation of eight breeding lines in SV field experiments to assess the shelf-life of processed salad and whole heads.
- Compiling and analyzing breeding line data, release germplasm notice.
- Experiment LD for three seasons: Evaluation of 162 RILs from BRG x Eruption and their parents for lettuce drop incidence in field experiments artificially infested with *S. minor* at the USDA, Salinas Research Station.
- Experiment PM: Evaluation of 162 RILs from BRG x Eruption and their parents for bolting in the LD field experiments at the USDA, Salinas Research Station.
- Tissue collection, DNA extraction and genotyping of 162 RILs from BRG x Eruption. Generation of SNP data. Construction of genetic map using SNP data.
- Mapping QTLs using the disease incidence and the genetic map datasets.
- Outreach: Results communicated at biennial meeting of the CLGRB (in March 207 and 2018) and the 2017 APS Annual Meeting.
- Publication of manuscript is expected to be released in 2019.

Increasing the number of seed companies conducting LD resistance breeding is the long-term objective of the project. To achieve this goal, the outcome measures proposed were: (1) tracking the number of requests for breeding lines; (2) article citations; and (3) requests for one-on-one consulting. A release notice has been prepared to release at least one LD resistant and high yielding romaine breeding line to the public in 2019 out of the eight breeding lines selected from the Hearts Delight x Eruption crosses. Sufficient amount of seed has been produced to distribute to parties interested in the materials. Results of the genetics part of the project has been summarized and the manuscript publication will be released in 2019. Once published, article citations and requests for research materials and one-on-one consultations will be tracked to monitor achievement of this goal. Judging from the number of people that visited the poster and requested a copy at the 2017 APS meetings, this information when published will be welcomed enthusiastically.

Goals established during the grant and actual accomplishments:

1. Map QTLs using qGene and QTLnetwork software as done in Hayes et al. 2014. J. Amer. Soc. Hort. Sci.: 139:388-398.
   - This activity was completed ahead of the scheduled timeline. All results were obtained and compiled; additional analysis was also conducted. This completes the activity.
2. Compile and analyze breeding line data, release germplasm.
   - This activity was completed ahead of the scheduled timeline. During the last reporting period, all results obtained were compiled and additional analyses conducted. Germplasm release notice has been prepared and will be released to the public in 2019. This will complete the activity.
3. Write and publish manuscripts.

- A manuscript was written, reviewed by all authors and has been submitted to the journal for publication. The publication is expected to be released in 2019. This will complete the activity.

4. Outreach: Communicate results at biennial meeting of the CLGRB and the ASHS.
   - This activity is continuous. Available results have been communicated at both venues and future progress will be further communicated as they become available.

Project Goals:
Goal 1: Increase the number of publicly available romaine breeding lines with LD resistance.
Goal 2: Generate new knowledge on the inheritance of LD resistance in Eruption and communicate this knowledge to lettuce breeders.
Goal 3: Increase the number of seed companies conducting LD resistance breeding.

Over 30 lettuce families were developed from a cross between cv. Eruption (latin type, resistant to LD) and cv. Hearts Delight (romaine type, susceptible to LD). These families were tested for resistance to LD, as well as other horticultural characteristics important for commercial lettuce production in three low desert field experiments. Based on their performance, eight breeding lines with superior resistance to LD were selected. These are the first breeding lines of romaine lettuce that have partial resistance to LD. This information was presented at the annual research conference of the CLGRB in March 2017 and 2018, that was attended by a diverse audience from various groups, including from the produce and seed industry. The target is to release at least one resistant and high yielding romaine breeding line to the public which will be released in 2019. The overall goal is to increase the number of seed companies engaged in LD resistance breeding to more than five a year after the completion of the project.

Eruption was previously demonstrated to have physiological resistance to LD. The objective of the current project was to determine the inheritance of resistance, identify the number and location of resistance genes and their relationship to genomic locations that underlie plant morphology (primarily bolting). The datasets required to accomplish this through genotypic data and phenotypic data were generated. Genotype data in the form of SNP markers has been generated through GBS for the BRG x Eruption RIL population. This RIL population and Hearts Delight x Eruption breeding lines were planted in the field and were evaluated against LD disease incidence (phenotype data) in spring and fall of 2016, and spring of 2017. The genotype and phenotype data were associated to determine the inheritance of LD resistance in the RILs and map the location of responsible genes. In general, consistent QTL were identified using the datasets from the three experiments. The QTL analysis identified one resistance QTL on each of lettuce chromosomes one and five, explaining 9-12 percent and 11-25 percent of the variation in LD, respectively (30-41 percent total). The LD resistance at these genomic locations is independent of bolting. This information was presented at the CLGRB Annual Research Conference in March 207 and 2018, that was attended by personnel from various groups, including lettuce breeders. Preliminary results were also presented at the 2017 APS Annual Meeting held in August that was attended by people including from breeding companies. A manuscript was written to communicate knowledge and tools generated to lettuce breeders and other scientists. Additional data generated was the determination of the location of a major gene that imparts Verticillium wilt resistance in Eruption.

The eight Hearts Delight x Eruption breeding lines selected are the first breeding lines of romaine lettuce that have partial resistance to LD. Once released, the use of these lines in breeding would enhance the breeding efforts for LD resistance. The study using the BRG x Eruption population would be the first to report the

inheritance of LD resistance in lettuce; two novel LD resistance QTL were consistently identified in more than one environment. The two together explained 30-41 percent of the variation in LD. Rapid bolting has been a major bottleneck for the use of genetic resistance in LD control. The LD resistance imparted by the QTL identified in this project is independent of bolting. Genetic markers associated with the QTL can readily be adapted to use in breeding. The detection of the *Vr1* gene in Eruption is also an additional highlight of the project outcomes.

Beneficiaries

LD is one of the economically important diseases of lettuce in the Salinas Valley of California and other lettuce growing regions. The disease causes a yield loss of up to 5 percent. In severe cases, total produce loss may result from LD. Use of genetic control introgressed from Eruption using knowledge generated by this project would potentially contribute to the reduction of the negative environmental impact of fungicides. The use of genetic control in integrated LD management would also provide additional benefits. The distribution of materials and knowledge generated through publication would impact lettuce producers, consumers, seed companies, commodity groups, public and private lettuce breeders and scientists.

The following is a list of beneficiaries in the lettuce industry:
Lettuce breeders: All lettuce breeding companies are expected to adopt the LD resistant breeding lines and the QTL identified by this project and use them in their breeding programs (roughly 20 plant breeding and biotech companies)
Growers: Around 120 growers in Salinas and Pajaro Valleys (estimate from CLGRB)
Consumers: Estimating 200,000,000 consumers. Over 200,000 acres in California supplying lettuce to over 20 packing companies could benefit from this research.

Lessons Learned

The project was carried out as planned. There were no major negative results. Being the first project to characterize the inheritance of LD resistance in lettuce, it was a successful project. The project demonstrated that reliable QTL could be identified by screening a mapping population in the field despite variations in levels of LD incidence among experimental seasons. The identification of *Vr1* for Verticillium resistance in Eruption helps future breeding efforts. Resistance against both LD and Verticillium wilt may be introgressed to breeding lines simultaneously. On the other hand, a lesson emerged from an activity initiated to develop a possible greenhouse screening technique. Results from greenhouse experiments were not consistent with data from the field. Some lettuce accessions with low levels of LD in the field had relatively higher levels of disease incidence in the greenhouse trials and vice versa. This observation indicated that regular greenhouse condition may not be suitable for LD evaluations. Thus, reliable LD incidence data in the greenhouse points to the difficulty of making comparisons among lettuce germplasm and selecting for breeding. For now, field screening is preferable to evaluate reaction of breeding lines to LD.

As indicated above, the attempt to develop a greenhouse screening technique provided the need to study the epidemiology of LD in relation to micro-environment (such as humidity, temperature and light conditions). Any future attempt to develop an inoculation technique in the greenhouse that may yield levels of LD incidence consistent with the field requires taking such information into account. Such a technique may then be adopted for screening lettuce germplasm against LD. In addition, this activity also indicated that lettuce tissue composition may contribute to LD resistance. This discovery has opened up a new line of research that will be pursued in the future.

All goals of the project were accomplished.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 52	**Project Title:** Adopting High-throughput Multiple Citrus Pathogens Detection System at Citrus Growers' Pest Detection Program	
Grant Recipient: Central California Tristeza Eradication Agency	**Grant Agreement No.:** SCB15052	**Date Submitted:** December 2018
Recipient Contact: Jill Barnier	**Telephone:** (559) 686-4973	**Email:** jbarnier@cctea.org

Project Summary

With over 50 years of evolving service to the San Joaquin Valley citrus industry, the Central California Tristeza Eradication Agency, operating the Citrus Pest Detection Program (CPDP) recognized a need to expand its diagnostic capabilities. By acquiring the necessary equipment, the CPDP saw an opportunity to implement high-throughput nucleic acid extraction. This would allow the CPDP to distinguish between mild and severe strains of *Citrus tristeza virus* (CTV), detect multiple pathogens in a single test, and address threats such as Huanglongbing (HLB), citrus stubborn, and other exotic pathogens, all for the greater protection of California's citrus industry.

California's $2.4 billion citrus industry has been acknowledged as the preeminent producer of fresh citrus in the world, supplying approximately 80 percent of this nation's fresh citrus fruit and approximately 92 percent of its lemons. California's citrus industry is currently faced with the threat of HLB, a potentially deadly disease. Learning from the rapid decimation of Florida's citrus industry following the establishment of HLB in that state, California's grower, research, and regulatory communities have taken proactive steps.

At the time of this grant proposal, Asian citrus psyllid (ACP), the vector of HLB, had been detected and generated quarantines in nine complete counties and portions of six others. The disease itself had been found and confirmed in only one urban location in southern California. In the ensuing period, ACP quarantines increased to include quarantines in all or part of 25 counties. HLB-infected trees have been found in several locations in four southern California counties, with total numbers over 700, but still confined to residential sites. This demonstrates the critical nature of making all possible resources available in the fight against this threat.

The CPDP was able to increase the total testing capabilities for the participating pest control districts as well as for the statewide industry, through cooperation with the California Department of Food and Agriculture and the California Citrus Pest and Disease Prevention Committee.

This projects builds upon the 2010 Specialty Crop Block Grant Program (SCBGP) Project 5: *Development of high-throughput assay for rapid and accurate detection of regulated citrus pathogens*. The prior project developed a method for high-throughput nucleic acid extraction and multiplex detection of HLB, CTV and other regulated pathogens. The current project expanded the ability for rapid and timely disease detection with the proven infrastructure already in place. Adoption of the Reverse Transcription quantitative polymerase chain reaction (RT-qPCR)-based high-throughput method by the CPDP has put the previously completed work into broader use while improving the CPDP's ability to detect CTV, HLB, citrus stubborn and other exotic pathogens (i.e., Citrus variegated chlorosis (CVC), citrus leprosis virus, etc.) of concern to growers now and in the future. Most critically

at present, it has provided an additional resource for timely detection of HLB in order to prevent its spread in commercial citrus.

Project Approach

It became clear early in the project that the equipment to be acquired had to be more specifically detailed. A meeting of the Technical Advisory Committee to the CPDP was held December 8, 2015. The meeting resulted in the addition of several pieces of equipment essential to the success of the project. Following equipment demonstrations and negotiation of best pricing, by December 31, 2015, orders had been placed for the majority of the special purpose equipment, which arrived throughout January and February 2016.

During this period, arrangements were made to establish a separate laboratory facility, a lengthy process requiring a county building permit and negotiation of a lease for a modular unit (all at CPDP expense). The new facility was ready for occupancy and installation of equipment in May 2016. Once installation was complete, required certifications (for the biosafety cabinet and polymerase chain reaction (PCR) workstation) were obtained and orientation and training on specialized equipment was conducted. On August 31, 2016, laboratory and regulatory staff from the California Department of Food and Agriculture, conducted an on-site visit, further clarifying best-practice expectations.

Beginning in September 2016, samples collected by field crews during spring 2016 operational season were used to begin standardizing protocols for the specific equipment acquired for:

1) Tissue preparation and grinding (Freeze dryer and Geno/Grinder® System).
2) DNA/RNA extraction and purification (KingFisher™ Flex Magnetic Particle Processors).
3) Quality assurance (Multiskan™ GO microplate spectrophotometer).
4) Sample and plate preparation (Multidrop™ Combi and Versette™ automated liquid handlers).
5) Pathogen detection (QuantStudio 7 PCR and QuantStudio 5 PCR).

Building on the protocols optimized and adopted to test CTV samples, in the next season attention shifted to *Spiroplasma citri* detection. Further improvements to protocols, to increase both efficiency and accuracy, were made for all critical functions: including chopping tissue, freeze-drying, grinding tissue, centrifugation, and qPCR testing. Once best procedures had been identified, efforts focused on increasing the volume of testing to achieve high-throughput productivity. The first season of PCR-related activity yielded 480 tests; during the 2017-2018 season 24,760 plant and 4,382 ACP PCR tests were completed.

In March 2017, the State Citrus Diagnostics Laboratory Permit 3323-L was received, authorizing the CPDP to screen non-regulatory plant samples for the HLB-associated bacteria as a California Department of Food and Agriculture permitted laboratory. In September 2017, an addendum was received from the California Department of Food and Agriculture allowing this facility to receive and process ACP samples for testing as well. In December 2017 the CPDP laboratory, successfully completed the analysis of the 2017 HLBPT02 panel and passed the HLB proficiency test. Also, in December 2017, the CPDP entered into a contract agreement with the California Department of Food and Agriculture to process and test ACP samples. A total of 30,936 tests were completed within the duration of the project.

Personnel timesheets were kept, and all grant funds were tracked to ensure that funds were used to solely enhance the competitiveness of specialty crops.

Project collaborators (Research Plant Pathologists from United States Department of Agriculture, Agricultural Research Service, Parlier and the University of California, Riverside) were instrumental in the standardization of protocols, specifically with multiplex quantitative PCR. The project team partnered with the Yokomi Laboratory, which led a screenhouse experiment studying the impact of CTV strains on commercial citrus cultivars. This experiment required RT-qPCR diagnosis of treated and untreated plants. High-throughput RNA extraction and RT-qPCR developed with the current SCBGP project was employed in testing 180 plants on multiple occasions. In addition, in collaboration with the Yokomi lab, two new strains of CTV were characterized in the CPDP laboratory by using newly designed primers and probe combinations in RT-qPCR.

Goals and Outcomes Achieved

The stated measurable outcome of this grant proposal was the expansion of diagnostic capability for multiple citrus pathogens at the Central California Tristeza Eradication Agency (CCTEA), to help the California citrus industry in prevention and/or management of current and potential exotic pathogens. This overall outcome was achieved by establishing a PCR laboratory at the CPDP, furnished with specialized equipment acquired with grant funds. Procedures were developed, tested, adjusted and refined, and tested again to standardize and optimize them for maximum accuracy and efficiency. Volume of samples and tests increased as high-throughput equipment and procedures were utilized for increasing productivity.

The first year of the project (2015-16) was focused on acquiring equipment and setting up the laboratory, so no testing occurred in that period. The second year (2016-17), as efforts turned to standardization and optimization of procedures, a total of 1,794 tests were completed. Increasing throughput was the goal of the third year (2017-18) of the project. In the fall of 2017, the CPDP piloted an HLB screening program, and expanded on it in spring 2018. The 2017-2018 testing period ended with a total of 29,142 PCR tests completed. It is anticipated that these numbers will continue to rise in the future.

The established goal for this project was to increase protection for the citrus industry through expansion of diagnostic capabilities at the CCTEA, which will increase the number and/or timeliness of disease-screening tests. Steps toward this goal were identified as:

1) Acquisition of necessary equipment. This step was completed in January 2016, with two subsequent additions.
2) Standardization and optimization of procedures. While fine-tuning is an on-going process, this step was essentially complete by fall 2017.
3) Implementation of the high-throughput nucleic-acid extraction method and RT-qPCR-based multiplex detection of various pathogens. As noted above, the testing numbers rose significantly through the course of the project and were expected to continue to do so as dictated by vector and disease pressure.

The purpose of this project was not to gather data, but to improve the ability of the citrus industry to maintain benchmarks as they were identified as the project commenced: The HLB pathogen had not been detected in commercial citrus, and severe isolates of CTV existed in the San Joaquin valley only in very low numbers.

Specified targets were stated as: to help prevent the establishment of exotic citrus pathogens (most specifically in the short term, to avoid Florida’s devastating HLB experience), to maintain suppression of existing

pathogens (i.e., severe CTV isolates), and to support regulatory agencies which are also testing for HLB and other regulated citrus pathogens in commercial citrus in California. The establishment of the PCR laboratory has positioned the CPDP to launch a monitoring program within its member pest control districts, to identify additional strains of severe CTV isolates, and to work cooperatively with the California Department of Food and Agriculture to increase the total amount of testing conducted in the state.

The major successful outcome of the project was the establishment of a PCR laboratory, with California Department of Food and Agriculture permits, ready and able to provide pest and disease testing for a variety of potential pest and disease threats to California's citrus industry in the heart of the San Joaquin valley.

Beneficiaries

Commercial citrus growers were the ultimate beneficiaries of this project. The laboratory at the CPDP was permitted by the state of California to accept and test citrus material to test for assorted pathogens. The samples to be tested may come directly from growers, from scientific researchers, from regulatory agencies such as the County Agricultural Commissioner or the California Department of Food and Agriculture, or from citrus pest control districts conducting screening survey programs.

California as a whole benefited indirectly from this project, as the CPDP's improved ability to assist in maintaining the health of California's $2.4 billion citrus industry contributed to the protection of thousands of jobs.

In the San Joaquin valley alone, it was estimated that there were approximately 5,000 commercial citrus growers, with over 220,000 acres. Statewide, the number of acres increases to nearly 300,000. The current threat to the industry is HLB, which in the five-year period following its discovery in 2005 cost Florida's economy $4.5 billion and 8,000 jobs, and to date has diminished that state's citrus production by about 70 percent. California's industry would be even more severely impacted since the bitter-tasting and misshapen fruits resulting from the disease would be unacceptable in the fresh fruit market. This project, establishing a PCR lab at the CPDP, was one of many proactive steps taken in California to prevent a progression similar to Florida's.

Lessons Learned

The ancillary necessities, outside the scope of the grant, for establishing the PCR laboratory were significantly greater than anticipated. These included housing (modular unit) and associated building permits, related support requirements such as installation of an ADA-compliant ramp and a fire suppression tank, and unexpected installation costs for large and weighty equipment.

In standardizing and optimizing procedures, it was discovered that the tissue preparation step was a severe bottleneck, and that several additional biosafety cabinets were required to achieve the production level needed. Considerable testing of tubes, caps, and capping systems was also necessary to achieve optimum results without cross-contamination.

There were no unexpected outcomes or results as a direct effect of the project. The challenges encountered were related to major underestimations of the additional infrastructure that would be required, and the time, effort, and expense related to housing the new laboratory.

While the number of samples projected in the project proposal (100,000) was not reached within the life of the grant, the significant annual increases in the number of tests suggested that it will be achievable in the future, as needed. The time required for acquisition, set-up, and procedures development was badly underestimated. True high-throughput processing did not really begin until the spring of 2018. Fortunately, the disease threat status did not yet call for the maximum productivity possible.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 53	**Project Title:** Development of Nematodes within the Genus *Phasmarhabditis* as Biocontrol Agents of Snails and Slugs in Californian Nurseries	
Grant Recipient: The Regents of the University of California, Riverside	**Grant Agreement No.:** SCB15053	**Date Submitted:** December 2018
Recipient Contact: Timothy Paine	**Telephone:** (951) 827-5835	**Email:** tpaine@ucr.edu

Project Summary

Snails and slugs are among the most damaging pests of California's specialty crops, but current controls are impractical for large areas and toxic to many non-target organisms. There is hence a real need for more effective and safe strategies. The Regents of the University of California, Riverside (UC Riverside) had recently discovered *Phasmarhabditis hermaphrodita* for the first time in the United States (U.S.), and this nematode, in combination with its bacterial associate, is used as a successful biocontrol of gastropod pests in Europe. Furthermore, survey results demonstrated that more than 80 percent of stakeholders in the Californian nursery industry would use biological control if available. This project aimed to determine the distribution of *Phasmarhabditis* spp. in California, assess their host range, assess the efficacy of candidate species in field trials, and deliver a safe agent for widespread use in Californian nurseries and other relevant specialty crops. Key public outreach initiatives included an enhanced project website, information dissemination and publications.

Invasive snails and slugs are among the most serious pest threats to California's specialty crops. They are direct pests of agriculture and horticulture; vector plant and human pathogens (e.g. *Escherichia coli*); and lower crop quality through fecal and mucus contamination. Management in California relies almost exclusively on molluscicides, with metaldehyde being the current active ingredient standard practice. Although generally effective and efficient (death within one day), it is very toxic to pets and, under high relative humidity, activity is lower and snails may recover. Iron phosphate and sodium ferric ethylenediaminetetraacetic acid are often used in high humidity conditions or where there are concerns about pet safety. Both materials act slower than metadehyde (two to seven days for death) and iron phosphate may be toxic to non-targets such as earthworms. Methiocarb is a restricted use material and is toxic to mammals including humans, birds, bees and aquatic taxa. Other control options (e.g. copper barriers) are impractical for large areas. There is hence an urgent need for more effective and safe strategies such as biological control. This project was timely as UC Riverside recently discovered the nematode *Phasmarhabditis hermaphrodita* for the first time in the U.S., in addition to two *Phasmarhabditis* spp: one new to science, and the other a new record.

The importance of this discovery in terms of gastropod management is evidenced by the number of pest gastropod species that attack nursery crops in California that are reportedly killed by *P. hermaphrodita*, and by the success of this agent (Nemaslug®) in Europe (e.g. approximately 70 percent reduction in damage to ornamentals). Also, this discovery opens possibilities for a more sustainable, safer strategy (biological control), either alone or as an integrated pest management (IPM) component for pest gastropods. This project aimed to determine the distribution of *Phasmarhabditis* spp. in California; determine their host range; assess the efficacy of candidate species in field trials and ultimately deliver a safe agent for widespread use in Californian nurseries.

This project built upon the 2012 Specialty Crop Block Grant Program (SCBGP) Project 59: *Development of a Biological Control Agent for Snail and Slug Pests of Nursery Plants in California*, in which project staff identified the key gastropod pests of the nursery industry in California and discovered a large number of nematodes associated with these key pests. The most promising nematode species are *P. hermaphrodita*, and two other species of *Phasmarhabditis*: one that was new to science (*P. californica*) and another a new record (*P. papillosa*). The remainder of the previous funding allowed assessment of the biocontrol potential of one species in microcosm experiments.

However, there is evidence that each of the nematode species has a unique distribution in California and it is likely that they are virulent to different gastropod species. To ensure the optimum agent or combination of agents is identified for widespread use in California nurseries, it was necessary to assess the potential of each species and conduct replicated field trials, which was necessary for this project do the research. In essence, the 2012 SCBGP Project 59 cast a 'broad net' in terms of finding potentially suitable biological control agents which provided a critical foundation for this current project. The project staff succeeded in discovering three species of slug- parasitizing nematodes in California. From the information generated in the 2012 SCBGP Project 59, nematodes in the genus *Phasmarhabditis* were identified as having the most potential (members of this genus have proven successful in European nurseries) therefore making it necessary to determine their true potential in California nurseries. Quantifiable impacts of previous research included heightened awareness that slugs and not snails are more damaging to nursery plants; demonstration of the urgent need for alternative control tactics to increase nursery crop yields and quality; demonstration of stakeholder demand for biocontrol; discovery of the malacoparasitic nematode, *P. hermaphrodita*, for the first time in the U.S. (Tandingan De Ley *et al*, 2014); discovery of two other species of *Phasmarhabditis* (Tandingan De Ley *et al*., 2016); identification of new invasive slug species that were not previously known to growers (Mc Donnell *et al*, 2014); identification of the inability of most growers to correctly identify damaging slug pests of nursery crops which consequently influences their ability to select the best strategy for control; and education of stakeholders on how to find, identify and manage snail and slug pests in nursery crops through invited workshop presentations and instruction (e.g. at California Association of Pest Control Advisers meetings).

Project Approach

A. Enhancement and maintenance of a project website:
The former Assistant Research Specialist in collaboration with the University of California Agriculture and Natural Resources (UCANR) Communication Services and Information Technology updated the project website (http://ucanr.edu/sites/CalSnailsandSlugs/). This website provides information on the most damaging species of snails and slugs in the nursery industry in California, detailed information on management strategies, contact information, and information on useful publications and websites. The aim of the site is to increase end-user knowledge of gastropod pests and their management in nursery plants in California.

From October 2015 through June 2018 the website was visited 11,587 times with a total of 19,773 page views. Of these visits, 10,799 were new users with the remaining 788 representing return visitors. Eighty-six percent of all visits to the website originated in the U.S. with California being the best represented state (73 percent). Furthermore, the website has received visitors from all 50 states within the U.S. as well as Washington DC, indicating the importance of this website for stakeholders on a national scale. In California, the cities where the website was accessed most often were Los Angeles (11.7 percent), San Francisco (8.6 percent), San Diego (6.6 percent), Sacramento (3.3 percent), and San Jose (3.2 percent). These five cities make up over one third of the traffic flow to the site. The most popular pages excluding the homepage were

California's Pest Snails and Slugs (29.1 percent), the Brown Garden Snail (12.1 percent), and Natural Enemies (8.1 percent).

B. Undergraduate and graduate recruitment and training:
During the course of this project, project staff hired a total of four undergraduate research assistants; two at no extra cost to the project; one was on a work study program. The Assistant Specialist recruited one assistant to help with snail and slug colony maintenance. The Associate Specialist recruited four undergraduate assistants to assist with culture media preparation, isolation and maintenance of nematode and bacterial cultures; preparation of semi-permanent nematode mounts for morphological examination and archiving; and PCR/molecular diagnostics. Two students were mentored through the UC Riverside Science, Technology, Engineering and Math (STEM) program, and one with the California Alliance for Minority Participation (CAMP). The Associate Specialist also mentored a PhD graduate student in the Microbiology and Plant Pathology program on bacterial isolation, maintenance, long-term storage, and molecular identification using 16S rDNA. All students were fully integrated into the research.

C. Gastropod collections and colony upkeep:
Gastropod collections were made in garden centers and plant nurseries in various counties throughout the state. The goals of these collections were to screen slugs and snails for species of *Phasmarhabditis* and to provide gastropod specimens for colony establishment and supplementation at UC Riverside. Excluding those collected in Riverside County for experiment purposes, a total of 1,054 slugs and snails were collected in Alameda, Kings, Madera, Merced, Monterey, Santa Barbara, Santa Clara, Stanislaus, and Ventura Counties. These specimens comprised of 11 species. Slugs were more diverse (six species) and more abundant than snails (five species). Of note was the collection of the slug, *Boettgerilla pallens* which was first reported (Mc Donnell *et al.* 2014) in the U.S. in 2014 (research supported by the 2012 SCBGP Project 59). The project staff have now collected this invasive species three times from three counties (Humboldt, Monterey, and San Mateo) in California.

Due to the recent California drought, project staff collected a limited number of slugs locally. Most of the slugs collected were *Lehmannia valenciana,* and rarely *Deroceras reticulatum.* The project staff started rearing *D. reticulatum* from eggs in the laboratory. Colony establishment continued despite problems related not only to availability but also episodes of mass mortality. Molecular diagnostics of cause showed the presence of obligate parasitic nematodes *(Cosmocercoides* sp) mainly on the *Deroceras laeve* colony. One virulence trial was discontinued because even the control slugs died from this nematode.

D. Recovery and identification of *Phasmarhabditis* spp from counties not previously surveyed:
Four new isolates were recovered and identified based on the D2D3 rDNA sequences. There was one *P. hermaphrodita* (ITD803) and three *P. californica* (ITD099, ITD808 and ITD815) from two new counties (Oakland and Salinas). *P. hermaphrodita* (ITD803) and *P. californica* (ITD808) were recovered in one nursery in Oakland. There are now a total of 21 isolates: Five of *P. hermaphrodita* from three slug hosts, three counties; 15 of *P. californica*, from four hosts, five counties; and one of *P. papillosa* in one county (Table 1). Although *P. hermaphrodita* and *P.californica* had overlapping geographical distribution (Humboldt, Sonoma, Oakland, Monterey), the latter was more widely distributed and was the only species recovered from *Arion hortensis*. The other hosts were *D. reticulatum*, *D. leave* and *L. valentiana*. *Phasmarhabditis* have not been recovered from snails. (Attachment 1, Table 1)

E. Host range and virulence of *Phasmarhabditis* spp on a range of target invasive gastropods and non-target species:

General Methodology:
All of the test gastropod species that were used in trials are considered to be pests of nurseries and garden centers in California (Mc Donnell *et al*. 2009) with the exception of giant African land snail (*Lissachatina fulica*) and decollate snail (*Rumina decollata*). Infective juveniles were obtained using a modified White trap technique (Wilson *et al*., 2012) and two rates (the recommended rate of 30 IJs/cm2 or 1x and 150 IJs/ cm2 or 5x) were compared with the non-treated control, in three of four replicate (depending on availability of slugs/specimens) plastic non-airtight disposable containers with autoclaved soil (75% SunGro Sunshine No. 4 mix and 25 % UCR Agricultural Operations mix) as the arena. On certain laboratory trials, lettuce leaf discs were introduced into each arena to demonstrate the effect of the treatments on slug feeding.

For the lath house trial, additional mesh shade and misters were provided because of unusually record temperatures. The experimental arena (treatments) consisted of bugdorm2 and the experimental units (*D. reticulatum*) were weighed and specimens of approximately similar weight were assigned to replications. There were three young hydrangea potted plants with three leaves, placed equidistantly on a mound of gravel at the center of the arena, the latter each having nine slugs. The use of bugdorms ensured non- transfer of slugs to other treatments. The six treatments were: (1) Non-infested control (plants only); (2) Slug-infested, untreated control (slugs and plants only); (3) Slug-infested, iron phosphate (SluggoTM at 1%) at the higher recommended rate of 1lb/ 1000 ft2); (4) Slug-infested, *P. hermaphrodita*-treated at 5x or 150 IJ/sq cm; (5) Slug-infested, *P. californica*-treated at 5x; (6) Slug-infested, *P. papillosa*-treated at 5x.

Results:
1. Infectivity of *Phasmarhabditis hermaphrodita* (ITD290) on Valencia slug (*Lehmannia valentiana*).
Three days after exposure (DAE), *L. valentiana* at the higher rate of 150 IJ/cm2 exhibited swelling of the mantle, that progressed to constriction of the area behind the mantle, exposure of the shell cavity, rupture of the integument and extrusion of the vestigial shell (Figure 1). At five DAE, slugs are dead or in varying degrees of symptom development with hundreds of nematodes swarming either in the “pool” of the shell cavity or over the cadaver. Percent survival was higher compared to the first trial (August 2015), however, from 14-21 DAE, treatment had significant effect on slug mortality ($p < 0.01$-0.001), with dose of 150 IJ/cm2 significantly higher than 30 IJ/cm2 (Attachment 1, Figure 1).

2. Infectivity of *Phasmarhabditis hermaphrodita* (ITD290) on tawny garden slug (*Limacus flavus*).
This was the first trial on the urban pest slug *L. flavus*, using isolate ITD290 of *P. hermaphrodita* following the same methodology. *P. hermaphrodita* caused mortality to *L. flavus*, however, effect was not statistically significant (Attachment 1, Figure 2). It was noted that nematode exposure caused 37.5 percent mortality on smaller specimens of *L. flavus* (in only one replicate) with symptom development that is very similar to *L. valentiana*, leading to death four DAE. This is the first record of *P. hermaphrodita* causing mortality and infecting *L. flavus*. Further test is needed to determine whether nematode susceptibility of this slug is size-and nematode species-dependent.

3. Infectivity of *Phasmarhabditis hermaphrodita* (ITD272) on grey field slug (*Deroceras reticulatum*).
D. reticulatum is widely regarded amongst scientists and farmers as the most damaging slug species in the world including North America. Symptom development on *D. reticulatum* is very similar to *L. valentiana*,

with characteristic swelling of the mantle, girdling behind the mantle, exposure of the cavity with numerous developing nematodes, and nematodes eventually decomposing the cadaver leaving only the vestigial shell (Figure 3). Percent mortality was highly significant between treatments, starting from two DAE ($p < 0.0001$) until the termination of the assay ($p < 0.0019$) 14 DAE.

D. reticulatum is highly susceptible to the nematode as mortality was observed at 150 IJ/cm^2 as early as two DAE (Figure 3). At this higher rate, mortality increased to 76 percent at 150 IJ/ cm^2 five DAE, 95.2 percent at seven DAE (complete control in two of three replicates) and complete control 14 DAE. At the lower rate of 30 IJ/cm^2, effect on slugs was significantly lower than at 150 IJ/ cm^2 at five to seven DAE (means of 28.6 percent and 42.9 percent mortality, respectively). However, application of 30 IJ/cm^2 was significantly as effective as 150 IJ/ cm^2 starting at nine DAE with means of 57 percent and 76 percent at nine DAE and 14 DAE, respectively. Results suggest that *P. hermaphrodita* was as effective at the lower rate of 30 IJ/ cm^2 to the higher rate of 150 IJ/ cm^2. *D. reticulatum* is highly susceptible, with average mortality (two trials) of 77 percent.

Feeding by *D. reticulatum* on lettuce discs was also inhibited following exposure to *P. hermaphrodita* with the most damage on control, non-protected arenas and the least damage on 5x treatments (Attachment 1, Figure 4).

4. Mortality and feeding inhibition of *Arion hortensis* exposed to *Phasmarhabditis hermaphrodita* (ITD272). The project staff also collected enough *Arion hortensis* so an assay was designed to determine if this species is susceptible to *P. hermaphrodita*. The findings revealed symptoms (Attachment 1, Figure 5) characteristic of *P. hermaphrodita* on susceptible *D. reticulatum* and mortality of over 50 to 72 percent (Trials 2 and 1, respectively) on *A. hortensis* one month after exposure to 150 IJ (5x) of *Phasmarhabditis hermaphrodita* ITD272 per cm^2 of soil. Feeding on lettuce discs was also inhibited on *Arion hortensis* exposed to *P. hermaphrodita* (Attachment 1, Figure 6) with the most damage on non-protected arenas and the least damage on 5x treatments. These findings are significant because this is the first observation of *A. hortensis'* susceptibility to *P. hermaphrodita*. This species was reported not susceptible to the commercial product Nemaslug® (Iglesias *et al*., 2001; Grewal *et al*., 2003).

5. Infectivity of *P. hermaphrodita* (ITD290) on giant African land snail (*Lissachatina fulica*).
An experiment was set up to test the isolate's efficacy on giant African land snail (*Lissachatina fulica; Achatina fulica*) neonates. *L. fulica* is listed as one of the top 100 and most damaging invasive species in the world (Lowe *et al.*, 2004), and is known from and problematic in North America (Lach and Cowie, 1999; Cowie, 2001). A United States Department of Agriculture (USDA) approved colony of this species is located in the restricted access Biosecurity Level 2 Quarantine Facility at UC Riverside, and this is where the trials with the species were conducted. Although not yet established as a pest outside of Florida and Hawaii, this species represents a serious threat to specialty crops in the U.S. and is being intercepted at air and sea ports. The same treatment arenas described in previous report were used, with eight *L. fulica* neonates per treatment. Mortality was also recorded at 5, 7, 9, 13 and 17 DAE.

Percent mortality was highly significant between treatments, starting from five DAE ($p < 0.02$) until the termination of the assay ($p < 0.01$), with 92 percent mortality recorded at the higher concentration of 150 IJ / cm2, increasing to almost 100 percent nine DAE until 17 DAE (Attachment 1, Figure 7). From nine DAE, 30 and 150 IJ / cm2 were equally effective. Mortality was rate dependent and giant African land snail neonates

are highly susceptible to *P. hermaphrodita*, with average mortality (two trials) of 80 percent. This is the first record of giant African land snail mortality following exposure to *Phasmarhabditis*.

6. Infectivity of *P. hermaphrodita* (ITD290) on Brown garden snail (*Cornu aspersum*). Percent mortality of *Cornu aspersum* was highly significant between treatments, starting from five DAE ($p < 0.0001$) until the termination of the assay ($p < 0.0137$) 21DAE. Percent mortality at 150 IJs/ cm2 was significantly higher than the recommended rate starting from 14 DAE and effects were comparable 21 DAE, highest at 95 percent (Figure 9). Brown garden snail is highly susceptible, with average mortality (two trials) of 80 percent.

7. Infectivity of *P. hermaphrodita* (ITD272) on *Discus* sp. During the year two gastropod survey, a large number of *Discus* sp. was collected enough to test one *Phasmarhabditis* sp. The same methodology and replicated experiment was performed to test its susceptibility to *P. hermaphrodita*. After a month of exposure to the nematode no mortality was observed. This suggests that *Discus* sp is not susceptible to *P. hermaphrodita*.

8. Infectivity of three *Phasmarhabditis* spp on Valencia slug (*Lehmannia valentiana*).
L. valentiana showed different levels of susceptibility to the three *Phasmarabditis* species. Percent mortality was significantly different among treatments five DAE ($p < 0.0388$) and 21 DAE ($p < 0.0520$) (Figure 10) with those exposed to 150 IJs/ cm2 of *P. papillosa* and *P. hermaphrodita* showing comparable means of 63 and 37 percent, respectively at 21 DAE; both significantly higher than the non-inoculated control treatment. Furthermore, at the extended observation of 34 DAE, mortality was significantly higher at 70.4 and 66.7 percent for *P. papillosa* and *P. californica* compared to all the other inoculated and non-inoculated treatments.

This is the first assay demonstrating virulence differences of three *Phasmarhabditis* species on *L. valentiana*. This slug species was chosen based on availability of specimens. Results suggest that *L. valentiana* is most susceptible to *P. papillosa* than *P. hermaphrodita* and *P. californica*. However, in a month after exposure, all three were able to kill more than 50 percent of the slugs with *P. papillosa* and *P. califonica* showing more virulence than *P. hermaphrodita*.

9. Infectivity of three *Phasmarhabditis* spp on decollate snail (*Rumina decollata*).
This assay was performed to determine the effects of the three *Phasmarhabditis* species on decollate snails that are used for biological control of young brown garden snails (*Cornu aspersum*) in specific areas in California like Fresno, Imperial, Kern, Los Angeles, Madera, Orange, Riverside, Santa Barbara, San Bernardino, San Diego, Ventura, and Tulare counties (http://ucanr.edu/sites/CalSnailsandSlugs/Management/Natural_enemies/). In this assay, fewer observations were made because decollates tend to burrow into the soil, thus making it difficult to collect data. Significant percent mortality between treatments at seven DAE on *P. papillosa*- treated snails. Percent mortality significantly increased to 62.5 percent at 21 DAE at 5x. *P. Hermaphrodita* and *P. californica* did not cause significant mortality either at 1x or 5x and are safe to non-target decollate snails. Tukey's pairwise comparison: means followed by the same letter do not differ significantly. Results suggest that *P. papillosa* was more virulent than *P. hermaphrodita* and *P. californica* to decollate snails and Valencia slugs. However, a month after initial exposure, all three nematode species killed more than 50 percent of the slugs, with *P. papillosa* and *P. californica* showing significantly more virulence than *P. hermaphrodita.* On decollate snails, *P. papillosa* was the only species that caused highly significant mortality from 7-21 DAE.

The data from this preliminary study suggest that *P. hermaphrodita* and *P. californica* are less virulent to decollate snails while *P. papillosa* might provide better broad control where *R. decollata* becomes a pest compared to the commercialized *P. hermaphrodita* species. However, more trials will be needed to confirm this theory.

10. Virulence of three *Phasmarhabditis* spp on marsh slug (*Deroceras laeve*).
From one local nursery, project staff collected a large number of *D. laeve*, allowing to plan an assay with this species. The project staff maintained the slugs for at least two weeks in the laboratory and designed and set up an experiment to test the effects of *P. hermaphrodita* on this species. The same methodology was used as in previous virulence assays. However, results of this experiment were inconclusive because a number of the control slugs died and molecular diagnostics revealed that these slugs were infected with obligate parasitic nematodes (*Cosmocercoides* sp.). Fortunately, project staff found good colonies/source of *D. leave* on campus and for the first time, virulence of the three *Phasmarhabditis* species was compared on this slug. The same methodology was used for the previous trials except that a recommended lower rate (0.5lb/1000 ft2) of iron phosphate (SluggoTM) was included as one treatment.

D. laeve mortality due to *Phasmarabditis* spp was observed three DAE with virulence difference among the three species. One hundred percent mean mortality was observed five DAE to *P. papillosa*; 14DAE for *P. californica* and *P. hermaphrodita* at the same 5x application. When compared with the Nemaslug ® benchmark of about 70 percent at 30 IJ (1x), and applying the corrected efficiency formula (Abbott, 1925) this was obtained approximately at five DAE for *P. papillosa* and 14 DAE for both *P. hermaphrodita* and *P. californica*. For the first trial, analysis of variance at 14 DAE revealed highly significant differences among treatments with mean mortality from *P. hermaphrodita* treatment significantly lower than *P. californica* and *P. papillosa*; and 1x and 5x treatments significantly higher than the non-treated control. In the second trial, all three species caused highly significant mortality compared to the non-treated control and the molluscicide at the lower recommendation rate. Data suggest that mortality of slugs exposed to the lower iron phosphate recommendation (0.5 lb/1000 ft2) was at the same level as the non-treated control and was therefore ineffective for managing *D. leave*. The next (laboratory and lath house trials) will include the higher concentration (1 lb/1000 ft2) of iron phosphate. Results further suggest that *P. papillosa* may be more virulent than *P. hermaphrodita* and *P. california*.

11. Mortality and feeding inhibition of *water snail Succinea* sp exposed to three *Phasmarhabditis* species.
During one of the discussions with stakeholders, project staff learned that water snails are often encountered in their production areas and that they are willing to provide gastropods as test materials. Project staff first tested mortality after *P. hermaphrodita* application and in a second trial, compared the three *Phasmarhabditis* spp. Mortality of *Succinea* sp due to *Phasmarabditis* spp was observed a day after exposure with virulence difference among the three species. One hundred percent mean mortality was observed three DAE to *P. papillosa*; five DAE for *P. californica*; and six DAE for *P. hermaphrodita* at the same 5x application. As compared with the Nemaslug ® benchmark of about 70 percent at 30 IJ (1x), this was obtained at four DAE for *P. papillosa* and five DAE for both *P. hermaphrodita* and *P. californica*. Results suggest that *P. papillosa* is more virulent than *P. hermaphrodita* and *P. California* although analysis of variance six DAE revealed non-significant differences in mean mortality among the three species and between 1x and 5x.

12. Infectivity of *P. hermaphrodita* (ITD272) on four earthworm species. The same methodology was followed for this experiment using *P. hermaphrodita* (1x and 5x) on *Amynthas gracilis* (Alabama jumper),

Eisenia fetida (red wigglers), *Eisenia hortensis* (European night crawler) and *Lumbricus terrestris* (common earthworm). *P. hermaphrodita* did not parasitize nor cause mortality on four earthworm species but it did on the positive control *D. reticulatum*.

13. Infectivity of *P. hermaphrodita* (ITD272) on banana slug (*Ariolimax californicus*). Test on *Agrolimax californicus* exposed to two inoculum levels (1x and 5x) of *P. hermaphrodita* ITD272 showed no mortality more than one month after exposure suggesting that the nematode is safe for use in areas where this slug is located.

14. Field trial of three *Phasmarhabditis* species for biocontrol against *Deroceras reticulatum* in Hydrangea. This trial will be ongoing into year 2019.

F. Workshop for Stakeholders:
With the availability of gastropods early in year 2018, project staff prioritized conducting trials on virulence and host range. However, one of the team members presented a seminar on Biological control of slugs at the California Association of Nurseries and Garden Centers Research Committee Meeting. This was attended by stakeholders, nursery owners/managers and held at Altman's Plants, Perris, California; on September 27, 2017.

G. Publications and research networking:
Oral presentations in Scientific Conferences:
The Assistant Specialist and the Associate Specialist gave oral presentations at scientific meetings with abstracts published in their proceedings.

1. McDonnell, R. J, Tandingan De Ley I., & Paine, T.D. 2017. Discovery of *Phasmarhabditis hermaphrodita* (Nematoda) in the U.S. and its potential importance in the biological control of invasive gastropods. In Proc. 5th International Symposium on Biological Control of Arthropods; Langkawi, Malaysia, September 11-15, 2017. p29.
2. Tandingan De Ley I., McDonnell, R. J., & Paine, T.D. 2017. Susceptibility of invasive gastropods and non-targets to different *Phasmarhabditis* species in the US. In Proc. Golden Jubilee Conference of the Society of Invertebrate Pathology (SIP), University of California San Diego, La Jolla, August 13-17, 2017, p.15.
3. McDonnell, R. J, Tandingan De Ley I., & Paine, T.D. 2017. Gastropod-killing worms: Discovery of the parasite, *Phasmarhabditis hermaphrodita* (Nematoda), in the US and its lethality to pest slugs, snails and non- target organisms. 83rd Annual Meeting of the American Malacological Society (AMS), University of Delaware Laird campus, Newark, DE, USA. July 16-21, 2017. p55.
4. Tandingan De Ley I., McDonnell, R. J., & Paine, T.D. 2017. *Phasmarhabditis hermaphrodita* and its infectivity on invasive gastropods and non-targets in the US. In Proc. 49th Annual meeting of the Organization of Nematologists of Tropical America (ONTA), July 10-14, 2017; Universidad de Puerto Rico- Mayagüez, Puerto Rico, p.31.

Invited Presentations:

1. Biological control of slugs. California Association of Nurseries and Garden Centers Research Committee Meeting. Altman's Plants, Perris, California; September 27, 2017.

2. Department of Nematology Fall Quarter Seminar Series (Nematology 250), University of California-Riverside, CA; October 25, 2017. "Biological control of invasive gastropods using *Phasmarhabditis*: updates and perspectives."
3. Research Forum of the Southern Mindanao Agriculture and Aquatic Resources Research and Development; and University of Southeastern Philippines, Obrero, Davao City, Philippines; Nov 17, 2017. "Biological control of invasive gastropods in specialty crops in California using *Phasmarhabditis*: updates and perspectives."
4. Seminar hosted by Department of Biology, College of Arts and Sciences and Department of Plant Pathology, College of Agriculture; University of Southern Mindanao, Kabacan, Cotabato, Philippines; Nov. 20, 2017. "Biological control of invasive gastropods in specialty crops in California using *Phasmarhabditis*: updates and perspectives."
5. Department seminar, Institute of Plant Protection, Sichuan Academy of Agricultural Sciences, 20 Jingjusi Road, Chengdu, China; Nov. 24, 2017." Biological control of invasive gastropods in specialty crops in California using *Phasmarhabditis*: updates and perspectives."

To ensure that funds were used solely to enhance the competitiveness of specialty crops:
1. Gastropod collection for survey and colony establishment were only conducted in nurseries and garden centers throughout California.
2. Only stakeholders in the Californian nursery industry were present during the California Association of Nurseries and Garden Centers meeting.
3. All project funded purchases were used solely for this project and were stored in a designated Slug project cabinet in the laboratory of the Project Director with access limited only to project team members.
4. The lath house trial made use of an important ornamental (Hydrangea) as test plants and these were provided by collaborating wholesale nursery in Riverside.

A number of scientists and stakeholders assisted during the course of this research. Project partners provided *Succinea* and *L. valentiana* from their nursery, hydrangea plants used in the lath house experiment, and allowed project staff to collect gastropods from their nursery.

Goals and Outcomes Achieved

Goal 1: Increase end-user knowledge of gastropod pests and their management in nursery plants in California. Major activity towards achieving this goal, is the enhancement and maintenance of the project website.

Performance was measured and quantified using the number of visitors to the enhanced project website. The website (http://ucanr.edu/sites/CalSnailsandSlugs/), launched September 20 2013, provides information on the most damaging species of snails and slugs in Californian nurseries, detailed information on management strategies, a link to the grower survey, and information on useful publications and websites. Prior to implementation of this project, the website had attracted an average of 85 visitors per month. The project staff therefore targeted 1,500 visitors in year one (125/month), 2,000 visitors in year two (166/month), and 3,000 visitors in year three (250/month), or 6,500 total visits. Based on Google Analytics, from October 1, 2015 through June 2018 the website was visited 11,587 times (965/month) with a total of 19,773 (1,648/month) page views. The project staff have exceeded the target by 78 percent.

Goal 2: Develop an effective biocontrol thereby increasing the number of stakeholders who utilize this strategy. Benchmark: There are no biological controls available for gastropod pests in nurseries in California, so benchmark was zero percent.

Major activities towards this goal included gastropod surveys, nematode isolation and species diagnostics, comprehensive host range tests on target invasive gastropods as well as non-target species including earthworms and banana slug *Ariolimax californicus*. Optimizing nematode-species-bacterial assemblage had not been completed due to some technical problems encountered. Mortality tests were therefore done using xenic cultures but using *Alcaligenes faecalis* as food source because this bacterial species showed the most promise among the three tested in terms of the number infective juveniles produced in agar plates. Further quantitative tests will be needed to confirm the preliminary observation. Two trials are on-going into year 2019: one is the (first) lath house experiment to evaluate consistency of the laboratory results, comparing the three *Phasmarhabditis* species and Sluggo ® on *D. reticulatum* introduced on Hydrangea plants; a second trial to compare three *Phasmarhabditis* species and Sluggo ® on bigger specimens of *R. decollata* with pea plants.

Based on the preliminary results, the biological control efficiency of *Phasmarhabditis* species e.g. *P. hermaphrodita* on a range of invasive gastropods that were tested was comparable or better than what had been reported for Nemaslug ®. For the first time, project staff demonstrated its lethal effects against invasive species like *Lissachatina fullica* and *Arion hortensis* (in addition to other invasives that are confirmed susceptible in the trials), including native species *Succinea* sp and *Rumina decollata*. The safe applicability of *Phasmarhabditis* was demonstrated by its non-infecting four earthworm species and a native slug, *Agrolimax californicus*. Preliminary results also suggested *P. papillosa* may be more virulent and may have wider host range than the other two species *P. hermaphrodita* and *P. californica*, and if theory will be proven/confirmed by additional data, *P. papillosa* could be a better candidate for future commercialization than *P. hermaphrodita* (Nemaslug ®). The target adoption rate will only be measured three years post project completion.

The long-term goal was to ensure a biological control adoption rate of 20 percent three years after an agent becomes available. Given that project staff have demonstrated an increase in stakeholder demand for biological control since the start of the project and that stakeholder willingness to use biological control was measured at 100 percent in a survey, project staff are confident that this adoption rate will be met. Towards this goal, project staff are continuing the information dissemination through seminar presentations, lectures, and will also be writing articles in extension bulletins.

The significant findings and outputs are as follows:

1. Additional new susceptible hosts of *Phasmarabditis hermaphrodita* are added, namely: *Arion hortensis*, *Lissachatina fulica*, *Succinea* sp and *Rumina decollata*. *P. hermaphrodita* can cause 50 to 60 percent mortality on *Arion hortensis*, an invasive slug reported to be non-susceptible to Nemaslug®. *R. decollata* can be a biocontrol ally or a pest, and application of *P. papillosa* may be an option if it is regarded as a pest. Please see the summary table below (section additional information).
2. First demonstration in laboratory biological control tests that the U.S. strain of *Phasmarhabditis hermaphrodita* is lethal to *Rumina decollata*, and invasive gastropods *Lissachatina fulica* and *Arion hortensis*.

3. First tests on virulence comparison among the three *Phasmarhabditis* species; data suggesting virulence variation among them; with *P. papillosa* demonstrating more virulence and exhibiting a broader host range than either *P. hermaphrodita* or *P. californica*. This virulence was demonstrated on *Succinea* sp., *Deroceras laeve* and *Rumina decollata*.
4. *P. hermaphrodita* U.S. isolate applied at 30 IJ (1x) and 150 IJ (5x) per cm2 of soil does not cause mortality to and is safe to four species of earthworms [*Amynthas gracilis* (Alabama jumper), *Eisenia fetida* (red wigglers), *Eisenia hortensis* (European night crawler) and *Lumbricus terrestris* (common earthworm)] that are used in vermiculture and as fish baits.
5. *P. hermaphrodita* U.S. isolate applied at 30 IJ (1x) and 150 IJ (5x) per cm2 of soil does not cause mortality to and is safe to non-target banana slug *Ariolimax californicus*.
6. Publication of five peer-reviewed research articles and one book chapter during the course of this project.
7. Delivery of four oral presentations and publication of research abstracts in proceedings of international meetings/conferences.
8. Presentation of research progress and outlook in seminars, fora, and stakeholders' meeting in California.

Beneficiaries

Beneficiaries of this project include commercial producers (e.g. wholesale nurseries), non-commercial producers (e.g. home horticulturalists), California Pest Control Advisors, University of California Cooperative Extension, County Agricultural Commissioner employees, and societies concerned with nursery production (e.g. San Diego County Flower and Plant Association and California Association of Nurseries and Garden Centers).

Based on the 2012 Census of Agriculture (USDA 2015), there was a total of 46,947 farms ($26.5 billion) growing specialty crops in California. For the nursery, greenhouse, floriculture and sod (NGFS) sector alone, there were 3,890 farms with a market value of $2.6 billion. However, a wide range of other specialty crops from the vegetables, melons, potatoes, and sweet potatoes sector (VMPS; 6155 farms) including fruits, vegetables, culinary herbs/spices, and medicinal plants are vulnerable to gastropod damage; and growers of these are potential beneficiaries from this project. This project has had a direct positive impact on these stakeholder groups through increased awareness of the presence and potential damage of invasive snails and slugs in nursery and greenhouse plants and providing information on how to effectively manage these pests. Additionally, identifying a *Phasmarhabditis* species with good potential for biological control will contribute to development of a product that could be introduced to the market.

Lessons Learned

Frequent interactions with stakeholders gave an important resource on what the gastropod problems are in their production areas as well as other aspects of the business. For instance, project staff learned from nursery management that water snails (*Succinea* sp) may not cause direct damage on their plants, but are considered nuisance pests and potentially could cause huge indirect losses in sale if found in a horticultural shipment.

Pest control advisors are also important (a) links to stakeholders who are keen on supporting the research by way of providing hard-to-find test gastropods and/or test plants; and (b) information resource for emerging gastropod pests in the area. The above inputs allowed staff to (a) reprioritize and put the resources on important test materials that are available and (b) plan and stay ahead of the invasive emerging pest by preparing research proposals that are responsive to the needs of the NGFS sector.

Slugs and snails have increasingly become a concern as evidenced by the increasing number of visitors to the website. Such a resource is important for stakeholders in the industry.

Laboratory rearing of certain slug species e.g. *Deroceras reticulatum* had been a bottle-neck in the infectivity tests. Despite the best attempts in using disinfested containers, organic carrots for food, there are die-offs that may happen just before a planned experiment. *D. laeve* seemed to be more sensitive to laboratory rearing in containers and in one die-off episode, project staff identified obligate parasitic nematodes *Cosmocercoides* from dead slugs. The project staff therefore decided not to wait for 10-14 days prior to their use in experiments, and instead, allowed only a three-day feeding prior to use. The project staff also started growing them from eggs, although growth had been very slow. This type of colony maintenance is labor intensive, so in the future, project staff will be experimenting on the use of caged plants or flats with grow lights.

Some unexpected outcomes of implementing this project include:
1. Discovering that slugs and not snails were more abundant in Californian nurseries and consequently are likely to be more of a pest causing direct damage or loss than invasive snails in these production systems.
2. Discovering that water snails *Succinea* sp are nuisance pests that may cause heavy losses in post production stage and that nursery management only allows “zero snails” in their horticultural shipment.
3. Data suggesting that gonochoristic *P. papillosa* may be more virulent and has a broader host range than hermaphrodites *P. hermaphrodita* and/or *P. californica.*

Additional Information

Manuscript for Giant African land snail is in preparation and will be subitted in 2019.

Peer-reviewed Publications/book chapter:

1. Tandingan De Ley, I., Holovachov, McDonnell, R., Bert, W., O. R., Paine, T.D., & De Ley, P. 2016. Description of *Phasmarhabditis californica* n. sp. and first report of *P. papillosa* (Nematoda: Rhabditidae) from invasive slugs in the USA. *Nematology* 18, 175-193.
2. Holovachov, O., Boström S., Tandingan De Ley, I., McDonnell, R., Alvarado, S., Paine, T.D., & De Ley, P. 2016. *Alloionema similis* sp. n., a genetically divergent sibling species of *A. appendiculatum* Schneider, 1859 (Rhabditida: Alloionematidae) from invasive slugs in California, USA. *Systematic Parasitology* 93, 877-898.
3. Nermuť, J., Holovachov, O., Tandingan De Ley, I., & Půža, V. 2017. *Alloionema californicum* Nermuť, Půža, Mráček & Lewis, 2016 is a junior synonym of *Alloionema similis* Holovachov, Boström, Tandingan De Ley, Mc Donnell, Alvarado, Paine & De Ley, 2016 (Nematoda: Alloionematidae). *Zootaxa* 4324, 378-384.
4. Carnaghi, M., Rae, R., Tandingan De Ley, I., Johnston, E., Kindermann, G., Mc Donnell, R., O’Hanlon, A., Reich, I., Sheahan, J., Williams, C.D., & Gormally, M.J. 2017. Susceptibility of a protected slug (*Geomalacus maculosus*) to four biocontrol nematodes. *Journal of Biocontrol Science and Technology* 27, 294-299.
5. Tandingan De Ley I., McDonnell, R. J., Paine, T.D. & De Ley, P. 2017. Discovery of *Phasmarhabditis hermaphrodita* (Nematoda: Rhabditidae) in North America and implications for snail and slug management. In. Abd-Elgawad, M., Askary, T. & Coupland, J. (eds) *Biocontrol Agents: Entomopathogenic and Slug Parasitic Nematodes.* UK, CABI International, Wallingford. http://www.cabi.org/bookshop/book/9781786390004.

7. Mc Donnell, R.J., Tandingan De Ley, I., & Paine, T.D. 2018. Susceptibility of neonate *Lissachatina fulica* (Achatinidae: Mollusca) to a US strain of the nematode *Phasmarhabditis hermaphrodita* (Rhabditidae: Nematoda). Biocontrol Science and Technology. Manuscript in press.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 54	**Project Title:** Development of an Effective Attractant for Control of Leaffooted Plant Bug in Pomegranate, Pistachio, and Almond	
Grant Recipient: United States Department of Agriculture, Agricultural Research Service	**Grant Agreement No.:** SCB15054	**Date Submitted:** December 2018
Recipient Contact: John J. Beck	**Telephone:** (352) 374-5730	**Email:** john.beck@ars.usda.gov

Project Summary

Leaffooted bugs (LFB) inflict serious damage to California pomegranate, pistachio, and almond. Published studies report LFB are capable of vectoring pathogenic fungi into pecans and sorghum. California growers have reported an increase in intact pomegranate fruit that contain rotten arils, possibly due to introduced fungi during “sucking” of the fruit by LFB. Increases of LFB populations are also a concern to tree nut growers not only because of physical damage due to feeding, but also due to the reported ability of LFB to transport fungal spores, which may translate to an increase in aflatoxigenic fungi contamination in tree nuts. There is currently no sustainable tool available to growers for control or monitoring of LFB. This project addressed this need for a reliable attractant by investigating the use of host plant volatiles as an environmentally friend method of monitoring or controlling LFB.

In the 2014 growing season California pomegranate growers noted a large increase of LFB populations in their orchards. This sudden observed increase in 2014 may have been due to the mild winters that California had been experiencing, which increases survival of overwintering adults. Given the current mild weather in subsequent and projected years, pomegranate growers are likely to see consecutive years of large populations of LFB. Moreover, LFB are generalist feeders and are known to migrate into accompanying orchards (i.e., pistachio and almond), and are thus problems for these California specialty crops. There is currently no attractant for the LFB and thus this project was a timely response to address this problem before it proliferates further.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

There were several aspects of the project that were run concurrently and needed to produce results for each of the subsequent portions to continue successfully. The portions can be delineated as the following activities:

- Establishment of a healthy LFB colony. This was initially done at the former collaborators laboratory, then successfully transferred to the United States Department of Agriculture, Agricultural Research Service (ARS) facility in Albany, California. Additionally, the University of California (UC), Riverside collaborators maintained a LFB colony for behavioral bioassays.
- Collection of volatiles from various LFB host plants. Because LFB are generalist (numerous plants as a food source), the ARS laboratories collected the volatiles from the following host plants: pomegranate, tomato, almond kernels, pistachio kernels, orange, carrot, and green bean.
- Analysis of collected volatiles using gas chromatography coupled to a mass spectrometer (GC-MS) to identify the volatiles comprising each of the host plant odors.
- Evaluation of GC-MS data to determine compounds common to all host plants.

- Electrophysiological responses of LFB antennae to specific compounds in each host plant. Electroantennography (EAG) and GC-electroantennographic detection (GC-EAD) were used to identify compounds that elicited responses from LFB antennae.
- Compounds were then categorized by class and abundance in each host plant and blend formulations were developed and sent to collaborators for field trapping studies.

Each of these project portions were successfully accomplished with several iterations of blend formulations developed and sent to collaborators for field trapping studies in pomegranate, almond, or pistachio orchards. The electrophysiological studies were very successful in that numerous compounds were authenticated (positively identified using a commercial standard) and their ability to elicit a response from the LFB were recorded. A small library of compounds has been generated and is being used to formulate blends for field testing. The number of blends sent to the field is growing and the results from each iteration helps to identify active/necessary components for an attractive blend.

A favorable and unusual development was the formation of a LFB workgroup to address the need to find a collaborator to take over field trapping studies of LFB in pomegranate, pistachio, and almond orchards. This was necessary due to the unexpected withdrawal of the project's original collaborator. Though this withdrawal affected briefly the evaluation of candidate attractant blends, the formation of the workgroup brought in more expertise and expanded the overall scope of the project. These tangential projects will be carried on by the workgroup after the funded grant period.

Additionally, due to collaborative ties with other researchers, a separate but similar collaboration with Georgia (GA) peach and pecan growers was formed with the LFB Principal Investigator (PI). This collaboration will investigate a different species of LFB (*Leptoglossus phyllopus*) that is becoming a problem in GA orchards. Insights from this collaboration will be applied to continued research with California LFB in pomegranates, pistachios, and almonds.

Candidate blend approaches and similarity of volatiles within host plant odors may advance research into the LFB insect pest (*Leptoglossus phyllopus*) of GA peaches and pecans. This collaborative effort between the ARS PI and another ARS laboratory is solely supported by these two laboratories and not funded from this Specialty Crop Block Grant Program project.

UC Riverside Collaborators: investigated the optimal trap type to use for LFB. Performed all subsequent field trapping studies in California pomegranate, pistachio, and almond orchards.

Goals and Outcomes Achieved

- Establishment of a healthy LFB colony. This was initially done at the former collaborators laboratory, then successfully transferred to the ARS facility in Albany, California. Additionally, the UC Riverside collaborators also maintained an LFB colony for behavioral bioassays.
- Collection of volatiles from various LFB host plants. Because LFB are generalist (numerous plants as a food source) the ARS laboratories collected the volatiles from the following host plants: pomegranate, tomato, almond kernels, pistachio kernels, orange, carrot, and green bean.
- Analysis of collected volatiles using gas chromatography coupled to a mass spectrometer (GC-MS) to identify the volatiles comprising each of the host plant odors.
- Evaluation of GC-MS data to determine compounds common to all host plants.

- Electrophysiological responses of LFB antennae to specific compounds in each host plant. Electroantennography (EAG) and GC-electroantennographic detection (GC-EAD) were used to identify compounds that elicited responses from LFB antennae.
- Compounds were then categorized by class and abundance in each host plant and blend formulations were developed and sent to collaborators for field trapping studies.

Collection of volatiles from other LFB hosts will be ongoing. These profiles will assist in the formulations of future candidate blends, particularly if an attractant blend is orchard-specific and certain host plant odors are needed for LFB attraction in each affected crop. Field trapping studies will continue.

There were four goals of the grant project:

1) Perform in situ and repeat ex situ volatile collection experiments. Performance measure: Identification of unique/increased amounts volatiles via qualitative assessment of gas chromatograms. Benchmark: Verify or improve upon the initial 14 compounds. Target: Unique volatiles.
    a. Comparison of actual to projected goal: this goal was fully successful and surpassed via the analyses of other LFB host plants. Grant researchers now have a library of compounds that are common to all host plants, as well as volatiles that are unique to each host plant.
2) Identification of specific semiochemicals and/or inclusion into a blend. Goal: Use electrophysiological and/or behavioral LFB assays to assess bioactivity of unique compounds. Performance measure: Antennal responses based on amplitude magnitude, or attractancy responses of LFB in in-lab bioassays, with higher numbers of trapped insects indicating attractancy. Benchmark: Comparison to inactive compounds. Target: Bioactive compounds that attract LFB.
    a. Comparison of actual to projected goal: this goal was fully successful. A library of compounds that elicited electrophysiological responses from the antennae of LFB has been established and is the working foundation for the formulation of blends for field trials.
3) Formulation of an attractive blend at optimized ratio of active components. Goal: Optimized blend with maximum attractancy over entire growing season. Performance measure: Reproducible attraction of adult LFB in field trapping studies, in several replicates and over numerous host plant phenological stages. The UC Riverside developed insect monitoring system would trap and record insects visiting the candidate blends and blank controls in the field. A substantial and significant increase in the number of visits to the candidate blends will be the goal. Trap results will show higher capture numbers for effective blends. Benchmark: There currently is no benchmark attractant. Once a blend is found to attract, optimized blends will be compared to the initial attractant blend. Target: An effective attractant of LFB that can be used by pomegranate growers for monitoring LFB populations; and can also be used or modified for use in pistachio and almond for growers to monitor LFB populations.
    a. Comparison of actual to projected goal: an attractive blend has not yet been identified. Work is ongoing to identify an efficacious formulation with the correct components and at the correct ratio. The research team is aware that more than one blend may be necessary in each of the affected orchards (i.e., pomegranate, pistachio, and almond).
4) Development of an effective and inexpensive commercial product for pomegranate, pistachio, and almond growers to reliably monitor LFB. Number of growers adopting a developed blend can be obtained through communication with Pest Control Advisors and commodity groups (Almond Board of California; California Pistachio Research Board). If a commercial blend is formulated, the number of units sold can be correlated with pomegranate, pistachio, and almond growers reportedly using the product.

a. Comparison of actual to projected goal: a commercial company has expressed interest in any positive findings the research team obtains. Since no blend has yet been identified, this option will be explored as necessary.

A standard electrophysiological methodology has been successfully developed for the analyses of volatiles. This is illustrated by a library of compounds and the responses they elicit from the LFB. The research team continues to accrue trap capture data for all candidate blends and are comparing them to controls.

The major successful outcomes of the project are:

- 147 compounds were identified from the seven hosts surveyed to date
- 22 compounds have been positively identified for their ability to elicit a significant response from male and female adult LFB antennae
- More than 40 blends have been sent to the field trapping collaborators for evaluation in pomegranate, pistachio, and almond orchards

Beneficiaries

Groups that will be directly and positively affected by an attractive LFB blend will be California pomegranate, pistachio, and almond growers. Indirectly will be research groups such as Almond Board of California and California Pistachio Research Board, as well as California Pest Control Advisors and other researchers in the field of LFB.

Currently affected are other LFB or stink bug (a similar type of insect pest) researchers who will learn of these advances from publications and presentations.

Actual damage values are unknown, but assuming a 0.1 percent damage to each of the listed major crops (pomegranate, pistachio, and almond) can be controlled with an efficacious blend, these crops would save California growers $5.12 million annually. Because of the multiple crops affected by this insect pest, it is estimated that there are well over 1,000 California pomegranate, pistachio, and almond growers that will benefit from an efficacious LFB attractant. Additionally, the number of acres of each crop are estimated at: pomegranate 20,000; pistachio 300,000; and, almonds 800,000.

Lessons Learned

Because of the change in collaborators that performed the crucial field trapping assays there was a delay in maximizing the number of blends sent out for field study. Most important, was the critical help of impacted stakeholders and the associated researchers that helped form the new LFB Workgroup and led to the new collaborative efforts that ensured continuation of the field trapping studies.

A lesson learned was that good ties and frequent communication with stakeholders is invaluable for obstacles that can be encountered.

The final goal of an efficacious attractant blend has not yet been achieved. This may be due in part to the delay in field trapping studies. Research is ongoing despite the end of this grant period.

Additional Information

Book Chapter: See Attachment 1

Beck, J.J.; Gee, W.S.; Cheng, L.W. Higbee, B.S.; Wilson, H.; Daane, K.M. Investigating host plant-based semiochemicals for attracting the leaffooted bug (Hemiptera: Coreidae), an insect pest of California agriculture. In *Roles of Natural Products for Biorational Pesticides in Agriculture,* ACS Symposium Series. Beck, J.J.; Rering, C.C.; Duke, S.O. (eds). American Chemical Society, Washington, D.C. Vol. 1294, pp. 143-165. 2018.

Presentations (invited speaker underlined):

Exploration of California host plant-based semiochemicals to attract the leaffooted bug. Beck, J.J.; Gee, W.S.; Higbee, B.S.; Wilson, H.; Daane, K. M. Entomological Society of America Pacific Branch Meeting, Reno, NV. Jun 13, 2018

Pheromone and related attractants for leaffooted bugs in California nut crops. Wilson, H.; Millar, J.G.; Daane, K. Entomological Society of America Pacific Branch Meeting, Reno, NV. Jun 13, **2018**

Host plant-based semiochemicals for attracting the leaffooted bug, an insect pest of California agriculture commodities. Beck, J.J.; Chuong, J.N.; Gee, W.S.; Cheng, L.W. 254th American Chemical Society National Meeting – Roles of Natural Products for Biorational Pesticides in Agriculture Symposium. Washington, D.C. Aug. 20, 2017

Toward the identification of important semiochemicals of the leaffooted bug – a new intrusive insect pest of several California agricultural commodities. Beck, J.J.; Higbee, B.S.; Gee, W.S. Gordon Research Conference – Plant Volatiles. Ventura, CA. Jan. 31 – Feb 5, 2016

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 55	**Project Title:** Develop effective fumigation methods to control plant parasitic nematodes in orchard soil for successful replanting	
Grant Recipient: United States Department of Agriculture, Agricultural Research Service	**Grant Agreement No.:** SCB15055	**Date Submitted:** December 2018
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Project Summary

Many specialty perennial crops in California utilize soil fumigation to control parasitic nematodes and diseases for successful orchard replanting. Open-field perennial nurseries almost solely rely on soil fumigants to meet the California Department of Food and Agriculture's (CDFA) Nursery Stock Nematode Control Program because the presence of parasitic nematodes on nursery crops means 100 percent economic loss. The loss of methyl bromide (MeBr) has brought great challenges to nematode control in perennial fields because nematodes are often present down to five-foot depth. The alternatives to MeBr, 1,3-dichloropropene (1,3-D, Telone®) and chloropicrin, cannot be delivered below three-foot soil depth with the existing fumigation methods (18-inch injection depth) that has resulted in significant survival of plant parasitic nematodes in deep soil after fumigation. Furthermore, stringent regulations on fumigant use are being modified continuously because emissions increase exposure risks to workers/bystanders and the release of volatile organic compounds (VOCs) as air pollutants. Loss of fumigants to growers will have serious economic consequences. Thus, modifications of current fumigation methods and/or innovative approaches are needed to ensure good efficacy, reducing emissions, and ultimately maintaining the availability of fumigants for agricultural use. The project objectives were to develop effective fumigation methods that could deliver fumigants to deeper soil and reduce emissions using deep injection, biochar amendment, low permeability tarp, or a combination of these techniques in broadcast or strip (tree row) applications to achieve good nematode control, low emission, and improvement on tree performance. The project will directly benefit the almond industry and also other specialty perennial crop growers who face the challenges in plant parasitic nematode control.

This project will provide data that directly benefit almond growers and also other specialty crops (stone fruits, nuts, and grapes) as they require similar fumigation or soil disinfestation for replanting. These crops have a total value of over $10 billion. The impact analysis is given here for almond alone. United States almonds are almost entirely produced in California and the acreage has grown from 545,000 acres in 2002 to 790,000 acres in 2012, producing a farm value of $4.8 billion ($3.4 billion as exports). However, there is also an increase of almond imports from 1.9 million pounds in 2002 to 15.9 million pounds in 2011, suggesting increased market competition. The competitiveness and sustainability of the industry has been relying heavily on successful pest control to produce clean planting stock and productive orchards. With the phase-out of MeBr, the few alternative fumigants registered for these uses are not only highly regulated because of the potential exposure risks to workers/bystanders and VOC emissions, but also less effective in controlling nematodes partially due to their lower mobility in soil. Recent years of research showed no control of nematodes in deep soil with the MeBr alternatives. This project will develop the strategies to improve nematode control in deep soil while minimizing emissions. Plant-parasitic nematodes are estimated to infest up to one third of California’s almond and stone fruit acreage (approximately one million acres). Fumigation will remain valuable to these sectors and this project is intended to develop methods with high fumigation

efficiency. Assuming 50 percent of the infested field growers chose fumigation, the project will benefit 0.5 million acres of orchard production for specialty crops. The ultimate goal is to increase/improve sustainable production in orchards by using effective fumigation methods with minimized environmental impact that will in turn help maintain fumigant availability to the specialty perennial crop growers mentioned above.

Although this project does not directly build upon a previously funded Specialty Crop Block Grant Program (SCBGP) project, it does complement and enhance the 2011 SCBGP Project 56: *Increase Fumigation Efficacy with Alternatives to Methyl Bromide using Low Permeability Tarps*. This project demonstrated that totally impermeable film (TIF) can reduce fumigant emissions by over 90 percent. The research has contributed to the adoption of TIF as an effective means to control emissions. The project also confirmed that: 1) Fumigation improved new tree growth significantly, although long term performance is still being monitored; and 2) Reduced two thirds rate under TIF provided nematode control effectively as the full rate with no tarp or under standard polyethylene (PE) tarp in soils above three-foot depth. However, it was observed consistently that at the injection depth of 18 inches (in) in fields covered with TIF, Telone® C35 (containing1,3-D and chloropicrin) cannot move effectively to depths below three feet where high survival of nematodes in two infested fields was observed. Thus, new or innovative approaches, such as deeper injection rarely tested before due to higher energy requirement and biochar amendment, which improves soil properties and potentially reduce fumigant emissions and improves efficacy with a lower cost than tarps, are proposed. The 2015 project was proposed to address these challenges to evaluate the potential of deeper injection and biochar amendment to reduce emissions while providing good control of nematodes with potential reduced costs and/or benefit to improve soil productivity.

Project Approach

Activities completed during the grant period included the following:

1. Improve fumigation methods to provide effective nematode control in deep soil by modifying current fumigation method in broadcast (whole field) or strip (tree rows) through shank applications. Three fumigation trials were conducted to evaluate emission reduction strategies while increase fumigation efficiency.
    a. The first trial was conducted in an almond orchard to be replanted in Hughson, Stanislaus County (Hughson Trial). The objective was to evaluate the effects of two injection depths, two surface sealing methods (bare and totally impermeable film or TIF tarp), and three application rates (full or 100 percent rate, 2/3 rate, and zero or no fumigation as the control) of Telone® C35 (35 percent chloropicrin or CP, 63 percent 1,3-dichloropropene or 1,3-D, and 2 percent other ingredients) on fumigant emission, distribution in soil profile, and efficacy on nematodes as well as tree response to fumigation treatment after replanting. Almond trees were pulled out after harvest in fall 2016 and fumigation was carried out on November 14, 2016. Total 12 treatments with four replicates were applied in randomized complete block design. The field layout is shown in Figure 1. Measurements on fumigant movement were done in selected treatments on three replicates. All treatment plots were evaluated for tree response. Monitored fumigant measurement included emissions and concentration changes in soil profile. Soil samples down to five feet (ft) at one ft increment were sampled to determine survival of plant-parasitic nematodes from fumigation treatments and also for residual fumigant determination. Following fumigation, young almond trees were planted towards the end of January 2017 and tree growth was measured immediately after the tree was planted and continued through the end of 2017. The results are shown in Figure 2. Briefly, initial tree trunk

diameters immediately after planting were similar among treatments (Figure 1a) but after about one year of growth, significantly better growth was observed from fumigated treatments especially the deep injections or TIF treatments (Figure 2). Tree performance in non-fumigated control was the poorest. Results confirm that fumigation provides substantial benefits in orchard establishment.

Figure 1. Arial overview of the fumigation trial site conducted in Hughson, Stanislaus County (November 2016).

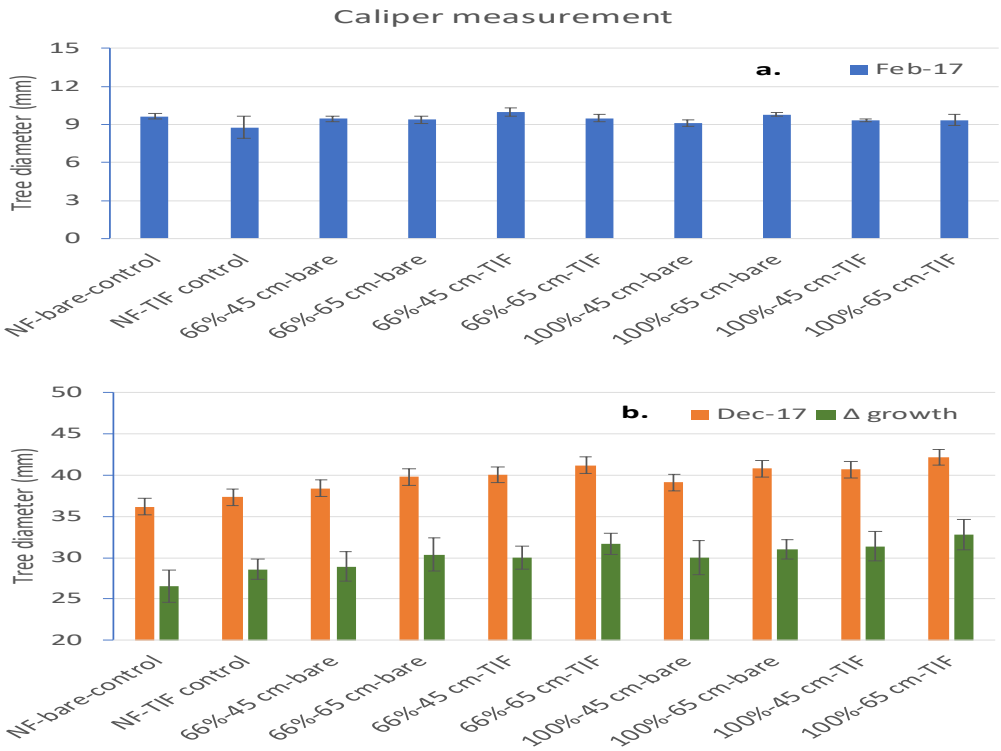

Figure 2. Caliper measurement for tree diameters a) immediately after planting in early 2017; and b) at the end of the year after fumigation treatment in 2016. Treatment: NF=no fumigation, bare, no tarp, 66 percent and 100 percent, Telone® C35 application rate, 45 and 65 cm fumigant injection depth in soil, and TIF, totally impermeable film.

b. The second trial was conducted at the United States Department of Agriculture, Agricultural Research Service (USDA ARS) San Joaquin Valley Agricultural Sciences Center at Parlier from October-November 2017. The objective was to determine effectiveness of two almond shell biochars on emission reductions in comparison with a coconut biochar, which was shown to be effective in reducing emissions at 40 ton/ha in the first field trial in 2016. Treatments applied were: 1) Control, 2) TIF (totally impermeable film), 3-5) almond shell biochar 550°C (AS char 550) at 15, 30, and 60 ton/ha, 6) almond shell biochar 900°C (AS char 900) at 30 ton/ha, and 7) coconut shell biochar (CS char) at 30 ton/ha. The almond shell chars were provided by the support of Almond Board. The CS char was CoolTerra™ biochar. Field plot size was 3.3 m x 3.3 m. Biochar was applied to surface soil that was incorporated into top 20 cm soil the day before fumigant injection. Nematode bags, which were infested with citrus nematodes, were buried at one-foot increments down to five feet prior to fumigation as well. On October 27, 2017, a mixture of 1,3-dichloropropene and chloropicrin (similar to Telone® C35 formula) was injected at 60 cm (24 inch) depth at 403 kg/ha using a Telone® rig with shank spacing of 50 cm (20 in). However, during fumigant injection, something unexpectedly occurred that ruined all treatments. The orchard was pulled out early in the year and soil was prepared before fumigant application. Although the soil was deep ripped several times before the trial, there were still large roots in the soil that were pulled up to the surface by the tractor, which dragged the roots along and scraped some surface soils treated with biochar from some treatments to others. As a result, the data were not consistent among three replicates for a treatment. Based on what occurred, a decision was made to repeat the field experiment, which led to the third trial.

c. May-June 2018 the third fumigation trial was conducted at USDA ARS research facility at Parlier again in the same field as the second field trial. Field operation was similar as that in the second trial, but smaller plots were used. Total of eight fumigated treatments were applied: control with no surface treatment, TIF tarp, and the three biochar (AS char 550, ACS 900, and CS char) at two rates (30 and 60 ton/ha). A non-fumigated control was used to determine efficacy. A mixture of 1,3-dichloropropene (65 percent) and chloropicrin (35 percent) that was similar to Telone® C35 formula was injected at the rate of total 400 kg/ha using a Telone® rig with shank spacing of 50 cm (20 in) to a depth of 60 cm (24 in). The injection was completed on May 15, 2018. Following the injection, soil was cultivated, disked, and rolled for compaction based on the label requirement. Biochar materials were then spread to soil surface evenly in a treatment plot and incorporated to top (0-10 cm) soil using a hand rotary cultivator. This allowed forming a relatively dense soil-biochar layer. Then prepared citrus nematode assay bags were buried in soil at 15 cm depth in each plot before installing TIF treatment and field sampling equipment including passive chambers and stainless steel capillary probes to collect emission and gaseous fumigant samples in soil. Sampling continued for three weeks. The nematode bags were retrieved to determine efficacy and soil samples were collected to determine residual fumigants.

Emission results from the third trial are shown in Figure 3 for 1,3-dichloropropene and chloropicrin. Total or cumulative emissions during the three-week monitoring are provided in Table 1. Note that emissions after two weeks of fumigant injection were negligible from all treatments. The results showed clear differences among the surface treatments. The highest emissions for both 1,3-D and CP were from the no-surface treated control. Almond char 550^{o}C reduced emission peak flux by about 50 percent or total emissions by about 20 percent in comparison with the control, but showed little difference between application rates. The almond char 900^{o}C reduced total emissions by 99 percent at both rates that were more effective than or comparable

with the coconut char (90 percent reduction) and TIF tarp (98 percent reduction). Good nematode control was achieved from all biochar treatments with no survival of citrus nematodes was observed in surface soil treated with biochars.

Figure 2. Field layout of fumigation trial conducted to determine effects of biochar on fumigant emissions, movement in soil, and nematode control at USDA-ARS, Parlier (May 2018).

Table 1. Cumulative emissions from different treatments in 2018 fumigation trial at Parlier

Treatment	**1,3-D (% of applied)[a]**	**CP (% of applied)**
Control - no surface treatment	22.72 (a)	5.45 (a)
TIF	0.45 (d)	0.00 (c)
Almond shell biochar 550C-30 ton/ha	14.03 (b)	2.31 (b)
Almond shell biochar 550C-60 ton/ha	13.31 (b)	1.79 (b)
Almond shell biochar 900C-30 ton/ha	0.19 (d)	0.02 (c)
Almond shell biochar 900C-60 ton/ha	<0.1 (d)	<0.1 (c)
Coconut biochar-30 ton/ha	2.39 (c)	0.71 (c)
Coconut biochar-60 ton/ha	0.63 (d)	1.37(b,c)

[a.] Means with different letters in the same column indicate significant differences at P<0.05.

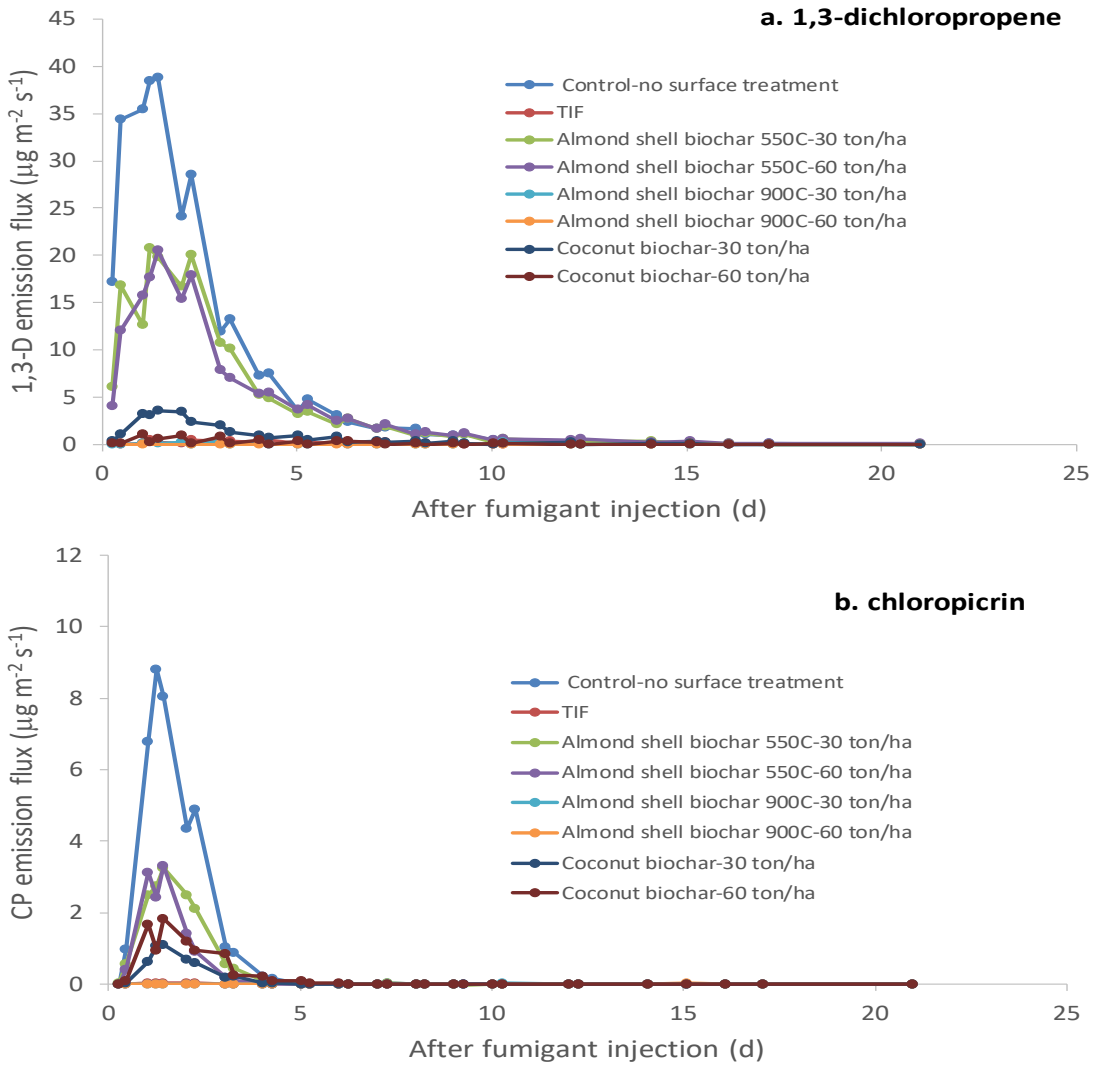

Figure 3. Emission flux of a. 1,3-dichloropropene (1,3-D) and b. chloropicrin from different surface sealing treatments. Error bars are omitted to improve readability.

2. Conducted laboratory experiments and examined the effects of the three biochar products tested in the 2018 field trial on degradation of fumigants. In summary, the biochar products had much stronger reaction with chloropicrin than 1,3-D. Almond char 900oC enhanced degradation of one 1,3-D isomers. The data partially support the findings in Figure 3 that the almond shell char produced at higher temperature reduced emissions more effectively.
3. Conducted outreach activities by giving several presentations to stakeholders at annual Almond Conference (2015-2017) and two international meetings (ASA and MABO international meetings) as well as via publications in scientific journals.

This project did not and does not benefit commodities other than specialty crops because only specialty crops use soil fumigants.

Each project collaborator has played an essential roles for the success of the project. The University of California (UC) Cooperative Extension Merced provided the leading role in establishing the first trial by identifying the field and working with the grower and TriCal to apply all treatments as well as monitoring tree growth during the project period. TriCal, Inc. provided full support and ensured fumigant applications by TriCal for all three fumigation trials. UC Davis played a crucial role in the project management at UC Davis and provided important insights and expertise for the project. UC Davis also determined nematode survival for soil samples collected from the field trials. A Research Leader from ARS coordinated project activities and provided essential support including personnel, travel, and project planning. In addition, visiting scientists from Chinese Academy of Agricultural Sciences (CAAS) participated in the last two field trials. CAAS conducted the laboratory experiment on biochar interaction with fumigants, performed sample analysis, and compiled all data including statistical analysis. The project leader from ARS lead all major activities and coordinated with all project collaborators to ensure that all tasks were completed on time, supervised data collection, and prepared the reports.

Goals and Outcomes Achieved

The overall goal for the project was to increase/improve sustainable production in orchards by using effective fumigation methods with minimized environmental impact that will in turn help maintain fumigant availability to the specialty perennial crop growers. All outcomes have been achieved due to the diligent efforts from the Project Director and all project participants.

The following items list the major successful outcomes of the project:

1) Increase knowledge and improvement in fumigation method that provide effective nematode control in deep soil by modifying current fumigation method in broadcast (whole field) or strip (tree rows) through shank applications.

   This outcome was accomplished by completing the 2016 fumigation trial. The trial tested regular (45 cm injection depth) and deep injection (65 cm depth) on fumigant movement and efficacy. The deeper injection clearly showed lower emission and delivered fumigant more effectively to greater depths. The results show that the deeper injection will improve nematode control. The regular injection depth could not deliver fumigants to soil below one meter (m) depth that resulted in high population of surviving nematodes. Results from the field trial have been presented in Almond Conference with 300 attendees, the International Conference on Methyl Bromide Alternatives and Emission Reductions with 200 attendees, and also published in a peer-reviewed journal.

2) Develop an innovative approach using biochar amendment to reduce emissions while improving soil properties, eliminating material disposal, and potentially reduce fumigation costs.

   This outcome was met with the addition and completion the third fumigation trial. The project team conducted a preliminary test that showed a coconut shell biochar at 40 ton reduced significantly fumigant emissions. Biochar was more effective than the low permeability tarp TIF and had no impact on nematode control (Figure 3). Data also showed that biochar increased persistency of fumigants in surface soil. The coconut shell biochar was not produced from locally available feedstock therefore the material is expensive and less likely adoptable by growers. After the failed trial in 2017, the last trial was conducted

in May 2018, and it was successfully determined almond shell biochar that effectively reduced emissions from about 40 percent to 99 percent or as effective as low permeability tarp (TIF).

3) Optimum and/or feasible agricultural practices that not only provide good efficacy control but also minimize emission loss and reduce costs.

   This outcome was achieved by conducting the first and the third fumigation trials. The project team determined that the current fumigation equipment was able to inject fumigants to a deeper depth of 60-65 cm depth that allows better delivery of fumigants and reducing emissions. The 2017 fumigation trial determine successfully that biochar products can reduce emission as effectively as TIF, but with additional benefits to sequestrate organic carbon, improve soil physiochemical properties, and reduced costs comparing with the plastic tarp. There is still substantial work to develop more effective biochar materials from local feedstock, but the project confirmed that these methods are hopeful toward reducing fumigation costs, thus can be easily adopted by growers as important agricultural practice.

Some of the outcomes measures can be long term. For example, this project determined the high potential or an effective biochar product from local orchard material (almond shell) to reduce fumigant emissions, but there is still substantial work to produce and test more effective materials from local feedstocks. Further reduced rate, i.e., less than 30 ton, could still be effective in reducing emissions, but that will require additional field tests. The project biochar was produced specifically for research purpose and is not commercially available, thus no cost information is readily available. If it is cost effective, adoption of using biochar amendment as a management practice to reduce fumigant emissions can be quick and easy because of additional benefits to improve soil property or productivity.

Prior to the project, fumigant injection at regular depth did not provide efficient nematode control at lower depth. Increased injection depth resulted in fumigant delivery and distribution 20-25 cm deeper and reduction of emission peak flux by 40 percent or higher without other treatments.

Additionally, there was no data on the ability of biochar products, especially made from local orchard feedstock, to reduce emissions. This project has determined that biochar from almond shell especially produced at 900^{o}C can substantially reduce emissions as effectively as the low permeability tarp plus several other benefits to increase carbon sequestrations and improve soil property or productivity.

The project outcome measures were completed.

- Commercial fumigation equipment can inject fumigant from 18 inches to 24-26 inches depth that delivered fumigant as deep as 100 cm in soil profile. The regular injection depth showed negligible concentration at 100 cm.
- Trees after one-year growth from all fumigated treatments were significantly larger (up to five mm in diameter) than non-fumigated control. Trees in plots from deep injection (24-inch depth) of fumigant were all relatively larger than those from regular injection at 18-inch depth.
- All biochar amendments significantly reduced fumigant emissions. Almond char 550^{o}C reduced total emissions by about 40 percent in comparison with the control. The almond char 900^{o}C reduced total

emissions most effectively by 99 percent, which was more effective than or comparable with the coconut char (90 percent reduction) and TIF tarp (98 percent reduction).

- Good nematode control was achieved from all biochar amendments with no survival of citrus nematodes in surface soil treated with biochars.

Beneficiaries

Groups that will benefit are almonds, nuts, and vineyards as well as field nurseries that are required to produce clean stock while meeting the demands for emission control from soil fumigation. Other specialty crops such as strawberry and other fumigant users will also benefit when they adopt management practices that are environmental friendly or towards improving overall agroecosystem health.

The accomplishments made from this project can be a benefit to several commodities especially almonds, nuts, stone fruits, and vineyards that use soil fumigants for replanting. The biochar amendment strategy to reduce emissions also has the potential to benefit annual specialty crops such as strawberries. The economic impact of the project may be difficult to determine at this time as the effective biochar products tested in the project are not commercially available. However, the project has scientific data to conclude that biochar can be made effective to reduce fumigant emissions and costs can be less expensive than plastic tarp with no material disposal or adverse impact to the environment.

Lessons Learned

One of the lessons learnt during the project period is that anything could happen in field experiments due to multiple factors involved and extreme care must be given to ensure success. The second trial was planned very well and everything was in place (biochar applied to large plots, and nematode assay bags were buried to five ft depth) until fumigants were injected to soil. Although the field was deep ripped three times in both directions, there were still left-over roots that were dragged to surface by fumigation equipment and ruined the biochar treatments. Fortunately, with the support of ARS funds and resources, the trial was repeated the trial quickly prior to the project end.

There were no unexpected outcomes or results from the project.

Additional Information

Peer-reviewed journal articles:
Attachment 1: Emission and crop response in almond orchards fumigated with reduced rates of Telone® C-35 and low permeability film for nematode control. Crop Protection. 2018. 105:80–89.
Attachment 2: Deep injection and the potential of biochar to reduce fumigant emissions and effects on nematode control. J. Environ. Manag. 2018. 223: 469–477.

Proceedings:

1. Emission, pest control, and crop response in almond orchard soil fumigation. p. 2(1-3) in Proceedings 2015 Annual International Research Conference on MeBr Alternatives and Emission Reductions, San Diego, California, November 8–10, 2015 with approximately 200 attendees.
2. Deep injection and biochar amendment on fumigant emissions and nematode control. p. 73:1-3 in 2017 Proceedings Annual International Research Conference on MeBr Alternatives and Emission Reductions, San Diego, California with approximately 200 attendees.

Presentations:

1. Minimize emissions and improve efficacy with low permeability tarp and deep injection in soil fumigation. Poster presentation at the Almond Conference, December 8–10, 2015, Sacramento, California with approximately 300 attendees.
2. Invited oral presentation at Almond Conference, December 8–10, 2015, Sacramento, California with approximately 300 attendees.
3. Minimize emissions and improve efficacy with low permeability tarp, reduced rate, and deep injection in soil fumigation**.** Poster presentation at the Almond Conference, December 6-8, 2016, Sacramento, California with approximately 300 attendees.
4. Field tests on biochar to reduce emissions from soil fumigation. Poster presentation at ASA-CSSA-SSSA International Annual Meeting, October 22–25, 2017, Tampa, Florida with approximately 500 attendees.
5. Effective ness of biochar to reduce fumigant emissions in field tests. Poster presentation at the Almond Conference, December 5–7, 2017, Sacramento, California with approximately 300 attendees.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 56	**Project Title:** Improving Strawberry Gray Mold Management through Identification of Ineffective Sprays	
Grant Recipient: Cal Poly Corporation	**Grant Agreement No.:** SCB15056	**Date Submitted:** December 2018
Recipient Contact: Gerald Holmes	**Telephone:** (805) 756-2120	**Email:** gjholmes@calpoly.edu

Project Summary

Gray mold, caused by *Botrytis cinerea*, is the most important disease affecting strawberry fruit during field production and postharvest. Losses occurring postharvest are much more costly because of the financial inputs incurred from harvesting, packaging, cooling and transporting fruit, not to mention the risk associated with rejected product if decay is greater than 2 percent (U.S. Standards for Grades of Strawberries). Because the crop is continuously fruiting, the disease must be managed throughout a six to seven-month harvest period. Management of the disease relies heavily on the use of fungicides applied at 7 to 14-day intervals, resulting in 15 to 20 applications per season.

Botrytis is notorious for developing resistance to fungicides, rendering them less effective or completely ineffective. Resistance in *Botrytis* to seven different classes of fungicide chemistry has been documented in the eastern and southern United States, where resistance monitoring efforts have been in place for several years. Although California lags in resistance monitoring, fungicide resistance in gray mold has been documented in California strawberry fields.

In 2014, the authors of this proposal collected 30 isolates of *Botrytis* from three conventional strawberry fields in Santa Maria and Guadalupe, California. The isolates were assayed for resistance to 11 active ingredients, representing seven modes of action. Partial or complete resistance was detected in some isolates to all but two active ingredients (fludioxonil and fluopyram). One hundred percent of the isolates tested resistant to thiophanate-methyl, 80 to 90 percent were resistant to fenhexamid and pyraclostrobin, 30 to 50 percent were resistant to cyprodinil, pyrimethanil, iprodione and boscalid; less than 10 percent were resistant to fluxapyroxad. Only fludioxonil and fluopyram tested free of resistance.

Thus, while there are many fungicides available for controlling gray mold, the effectiveness of several products is compromised by resistance. Although 30 isolates is a small sample size, representing only one of the three major California production regions, at one point in time, these results are similar to what is being found in other production regions of the United States. It is critical to understand this problem more thoroughly by conducting an industry-wide resistance monitoring program. This project comprehensively surveyed the California strawberry industry for resistance to all major active ingredients registered for use against strawberry gray mold. The project employed well-established techniques that yielded reliable results. The results will provide the strawberry industry with information that ultimately will lead to avoiding the use of ineffective sprays resulting in improved disease management.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Sensitivity of *Botrytis cinerea* to seven fungicide chemical classes was determined for 888 isolates collected in 2016 from 47 California strawberry fields. Isolates were collected early-season (minimum fungicide exposure) and late-season (maximum fungicide exposure) from the same planting block in each field. Resistance was determined using a mycelial growth assay and variable frequencies of resistance were observed to each fungicide at both sampling times (early-season %, late-season %): boscalid (12,35), cyprodinil (12,46), fenhexamid (53,91), fludioxonil (1,4), fluopyram (2,7), iprodione (25,8), isofetamid (0,1), penthiopyrad (8,25), pyraclostrobin (77,98), and thiophanate-methyl (81,96). Analysis of number of chemical class resistances (CCR) revealed an increasing shift in CCR from the early- to late-season. Phenotypes of 40 isolates that were resistant or sensitive to different chemical classes were associated with presence or absence of mutations in target genes. Fungicide resistance phenotypes determined in the mycelial growth assay closely matched (93.8 percent) the genotype observed. Previously described resistance-conferring mutations were found for each gene. A survey of fungicide use from 32 of the sampled fields revealed an average of 15 applications of gray mold labeled fungicides per season at an average interval of 12 days. The most frequently applied fungicides (average number of applications during the 2016 season) were captan (7.3), pyraclostrobin (2.5), cyprodinil (2.3), fludioxonil (2.3), boscalid (1.8), and fenhexamid (1.4). Multifungicide resistance is widespread in California. Resistance management tactics that reduce selection pressure by limiting fungicide use, rotating among Fungicide Resistance Action Committee (FRAC) codes and mixing/rotating site-specific fungicides with multisite fungicides need to be improved and implemented.

All work plan items were accomplished as listed. Specifically, fungicide usage data was obtained from the Pesticide Use Report (PUR) database maintained by the California Department of Pesticide Regulation (CDPR). *Botrytis* isolates were collected from all districts in the early and late season of 2016 and isolates were shipped to Clemson University for testing against 11 active ingredients in eight FRAC codes. Results were disseminated to the industry by oral presentations at regional strawberry meetings, a hard copy bulletin reporting results and a webcast available online at Plant Management Network.

Gray mold is a disease unique to strawberries. Thus, this project does not enhance the competitiveness of non-specialty crops.

Clemson University: Clemson's lab has received and assayed *Botrytis* isolates for resistance to nine active ingredients. Clemson University also hosted a master's student for a week-long training.

Goals and Outcomes Achieved

Fungicide usage data was obtained from the PUR database maintained by the CDPR. *Botrytis* isolates were collected from all districts in the early and late season of 2016. After beginning the project, it became obvious that there was not sufficient budget or time to assay 3,000 isolates. The 888 isolates collected was sufficient to reach confident conclusions. The isolates were shipped to Clemson University for testing against 11 active ingredients in eight FRAC codes. Results were disseminated to the industry by oral presentations at regional strawberry meetings, a hard copy bulletin reporting results and a webcast available online at Plant Management Network (see Additional Information). There was a total of 15 meetings with approximately 1,500 total attendees. Over 300 copies of the bulletin were taken by attendees. There were over 800 visits to the webcast site and the bulletin was downloaded over 400 times.

The long-term benefits of this project include improved gray mold management through sound anti-resistance management. Growers can use the data generated to make more informed choices about fungicide use. This includes less reliance of resistance-prone active ingredients, increased rotation with different modes of action and mixing of site specific and multisite fungicides.

The goal to compare the reduction in pounds of active ingredients used to control *Botrytis* was not met. Final PUR data for pounds used from 2016 and 2017 should be available in 2019.

Fungicide resistance profiles
In conventional fields, 90% of isolates were resistant to pyraclostrobin, 86% to thiophanate-methyl, 66% to fenhexamid, 26% to cyprodinil, 23% to boscalid, 15% to penthiopyrad, 14% to iprodione, 4% to fluopyram, 2% to fludioxonil, and 1% to isofetamid. Resistance frequencies were significantly different ($p<0.0001$) between the early- and late-season for all active ingredients except fluopyram and isofetamid (Figure 1). Frequencies of resistance varied from district to district and from field to field within the same district. Resistance to isofetamid was only observed in three isolates from the late-season sampling of the Northern district. A subset of 95 isolates representing all districts were identified to be *B. cinerea* (94 isolates) and *B. mali* (one isolate).

Resistance phenotypes
The average Chemical Class Resistance (CCR) of isolates from late-season conventional fields was statistically higher than early-season conventional fields and organic fields at both sampling times (Figure 2). From conventional fields, there were 45 distinct resistance patterns among the 405 isolates tested for resistance to all seven FRAC codes (including pyraclostrobin). The most common resistance pattern was resistance to fenhexamid, pyraclostrobin, and thiophanate-methyl. Consequently, the most common CCR phenotype was 3CCR both in the early-season and late-season collections. Populations had significantly higher CCR values in the late-season compared to the early-season ($F[102] = 2.83$, p-value = 0.003). Staff only detected four 7CCR isolates during the late-season and only from the Northern district (Figure 3).

Molecular basis of resistance and isolate identification
To determine the range of target gene variations in California isolates, a total of 40 isolates from the Southern, Central, and Northern districts were subjected to genetic analysis. They were determined as resistant or sensitive to multiple fungicides in the mycelial growth assay. Several known resistance-conferring mutations were found within each target gene: F196C, F412I, and F412S within erg27; I356N, I365N, and I365S within bos1; E198A within the beta-tubulin gene; G143A within the cytb gene; R351C and the ΔL497 deletion within mrr1; and H272R, H272Y, N230I, and P225F within the sdhB gene. The ΔL497 deletion within the mrr1 gene is only found in *Botrytis* group S genotypes and is referred to as MDR1h (Leroch et al. 2013). P225F was the only mutation associated with resistance to isofetamid. Isolates with this mutation were also cross-resistant to penthiopyrad, fluopyram, and boscalid. One isolate sensitive to pyraclostrobin contained a previously reported type I intron after codon 143 of the cytb gene (Leroux et al. 2010).

The fungicide resistance phenotype determined in the mycelial growth assay matched largely (61/65 matches; 93.8 percent accuracy) with the absence or presence of target gene mutations. Exceptions include two isolates (660 and 118A) that were sensitive to pyraclostrobin but revealed the G143A mutation; retesting confirmed both were resistant to pyraclostrobin. Another two isolates (44 and 746) were sensitive to boscalid but had the H272R mutation; retesting confirmed they both were resistant to boscalid.

Fungicide use survey

From the survey, staff observed that fungicide applications were made throughout the harvest season. Harvest began and ended at different times for the three regions, but the average time between the first and last fungicide application was approximately six months. There was an average of 15 fungicide applications at an average interval of 12 days. The growing district did not significantly affect the frequency of fungicide use ($F[2,742] = 1.583$, p-value = 0.206). The resistance management recommendation of rotating modes of action was universally employed. Captan, a multi-site fungicide, was the most frequently applied fungicide, while thiram (also multi-site) was rarely used (Figure 4). The cyprodinil+fludioxonil premix, boscalid+pyraclostrobin premix, and fenhexamid were the most frequently applied site-specific products in the 32 surveyed fields.

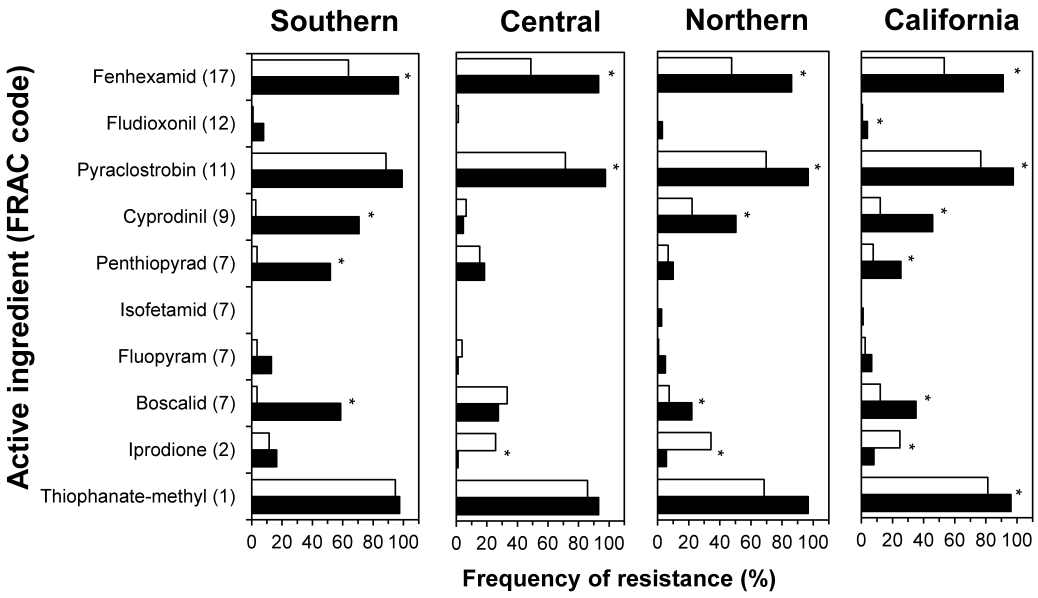

Figure 1. Early-season (white) and late-season (black) frequencies of resistance to ten active ingredients with isolates of *Botrytis cinerea* collected in conventional fields of the Southern (n=229), Central (n=165), and Northern (n=308) strawberry growing districts of California. Fewer isolates were tested for resistance to pyraclostrobin in the Southern (n=120), Central (n=97) and Northern (n=188) districts. Statistical significance of frequency of resistance between sampling times is represented by and asterisk (*) ($p<0.05$).

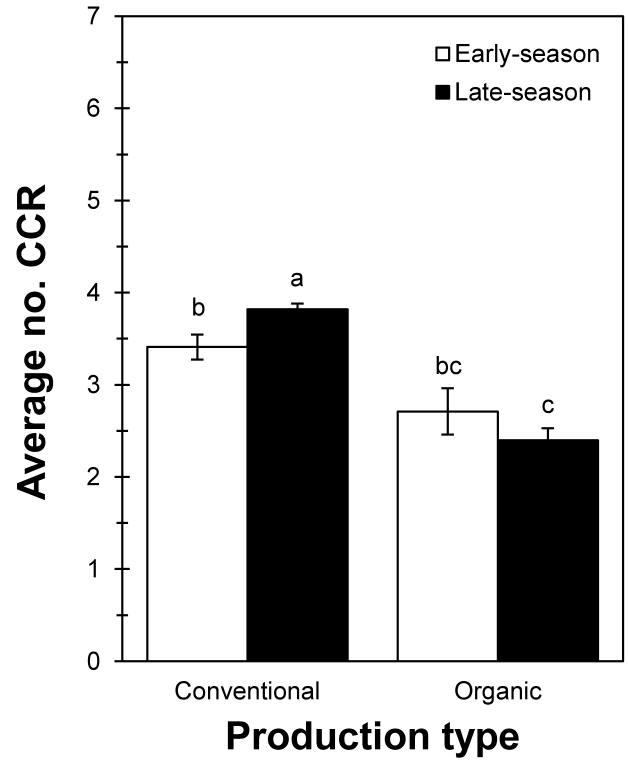

Figure 2. Average number of chemical class resistances (CCR) of *Botrytis cinerea* isolates collected early- and late-season from conventional (n=405) and organic (n=103) California strawberry fields. Error bars are standard error of the means. Bars with different letters are significantly different according to a post-hoc Tukey's honest significant difference test (α=0.05).

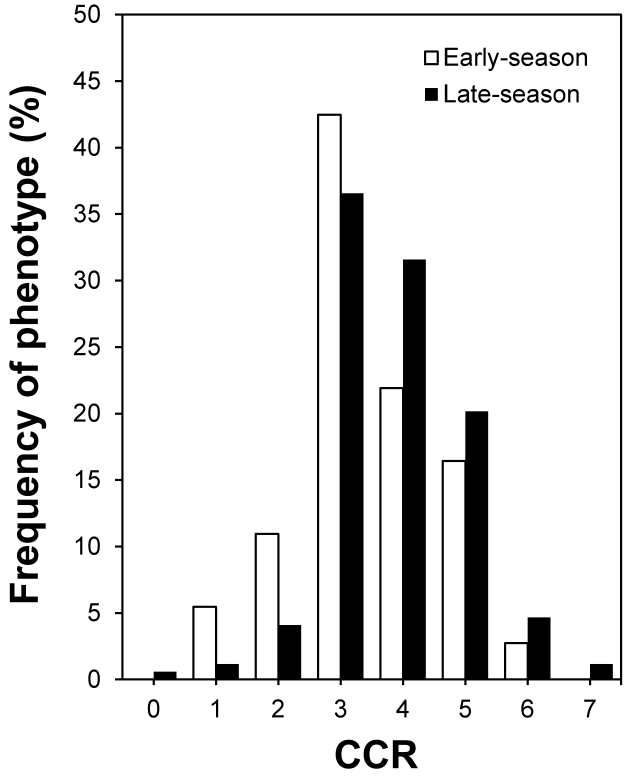

Figure 3. Early-season (n=71) and late-season (n=334) frequencies of chemical class resistance (CCR) phenotypes from *Botrytis cinerea* isolates collected in conventional fields of the Southern, Central, and Northern strawberry growing districts of California.

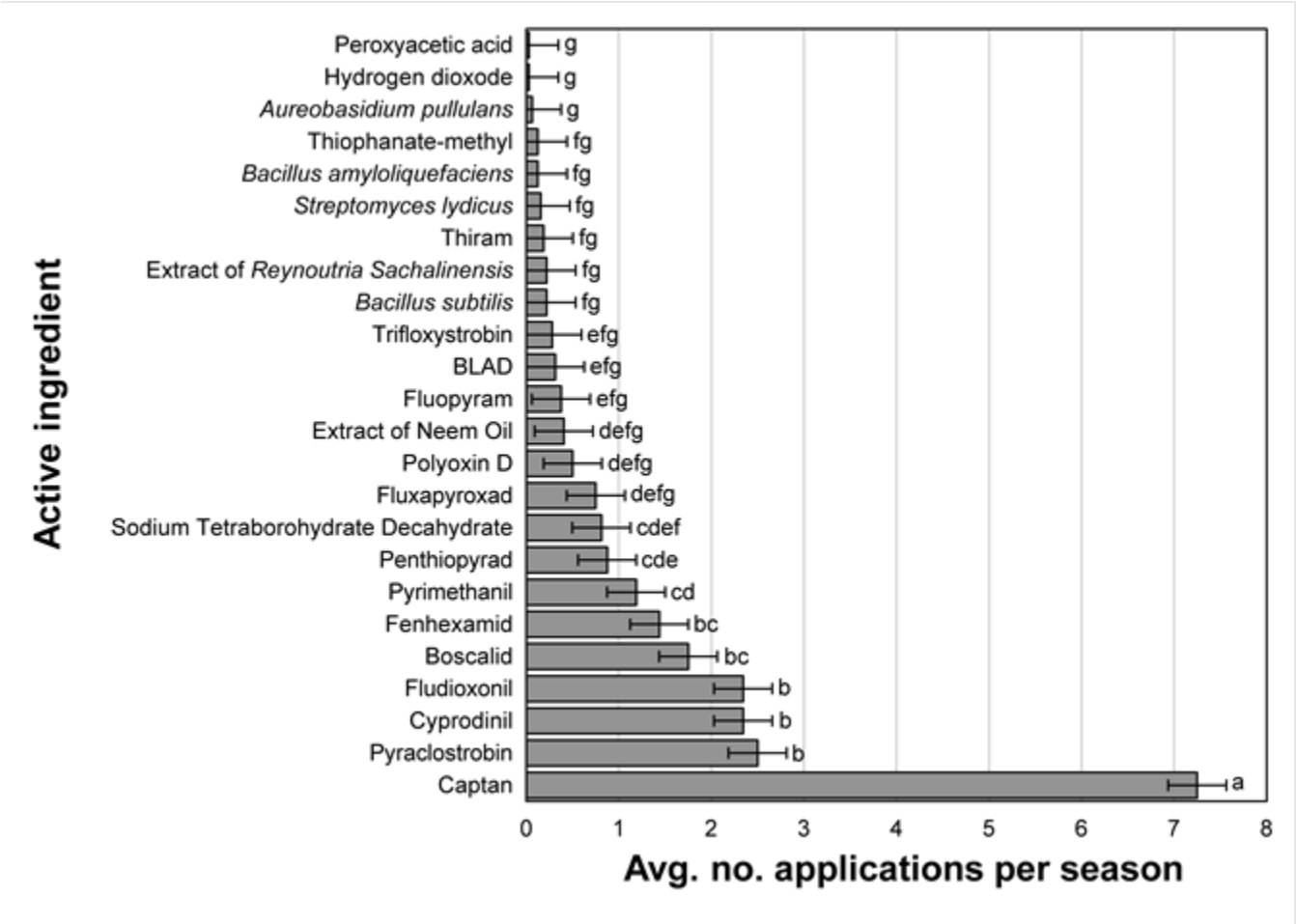

Figure 4. Average number of applications per season of active ingredients labeled for gray mold of strawberry in 32 California conventional strawberry fields in 2016. Error bars are standard error of the means. Bars with different letters are significantly different according to a post-hoc Tukey's honest significant difference test (α=0.05).

Major successful outcomes:

- Documented resistance to fungicides used against *Botrytis* gray mold.
- The most common resistance pattern was resistance to fenhexamid, pyraclostrobin, and thiophanate-methyl.
- There was an average of 15 fungicide applications at an average interval of 12 days.

Beneficiaries

There are over 400 strawberry growers, over 20 pest control advisors, and at least 30 technical reps from fungicide registrants that benefited from this project.

An estimated 5 percent of the California strawberry crop ($100 million) is lost to *Botrytis* annually. It is estimated that improving strawberry gray mold management can reduce loss by up to 50 percent, or $50 million dollars.

Lessons Learned

- Collaborate with people who have already mastered the assay. This saves time and improves results.
- Meet frequently to discuss progress. This identifies problems early and keeps progress on track.
- Work closely with industry. Without industry collaboration, much of the project would not be possible. Industry provided access to fields and information about fungicide use.

Unexpected result:
Discovered new *Botrytis* species – *B. mali*

Additional Information

Publication: Cosseboom, S. D., Ivors, K. L., Schnabel, G. and Holmes, G. J. 2018. First report of *Botrytis mali* causing gray mold on strawberry in California. Plant Dis. 102: 679. https://doi.org/10.1094/PDIS-10-17-1539-PDN

Cosseboom, S., Schnabel, G., Ivors, K. and Holmes, G. 2016. Resistance to *Botrytis cinerea* to fungicides in California strawberries. (Abstr.) Phytopathology 106:S4.1. http://dx.doi.org/10.1094/PHYTO-106-12-S4.1

Cosseboom, S. D., Schnabel, G., Ivors, K. L. and Holmes, G. J. 2017. Resistance of *Botrytis cinerea* from California strawberries to ten fungicides. (Abstr.) Phytopathology (in press)

Cosseboom, S. D., Ivors, K. L., Schnabel, G, Bryson, P. K. and Holmes, G. J. 2018. Within-season shift in fungicide resistance profiles of *Botrytis* cinerea in California strawberry fields. Plant Disease (submitted)

Webcast: https://www.plantmanagementnetwork.org/edcenter/seminars/Outreach/Strawberry/Botrytis/

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 57	**Project Title:** Developing a More Sustainable Pest Management Program for Southeast Asian Farmers	
Grant Recipient: The Regents of the University of California, Agriculture and Natural Resources	**Grant Agreement No.:** SCB15057	**Date Submitted:** December 2018
Recipient Contact: Ruth Dahlquist-Willard	**Telephone:** (559) 241-7513	**Email:** rdahlquistwillard@ucanr.edu

Project Summary

Small-scale Southeast Asian farms in California have a large diversity of specialty crops grown in complex polycultures, including many unique Asian specialty vegetables such as traditional squashes, yardlong beans, Thai chili peppers, bittermelon, and bok choy as well as mainstream crops for farmers markets. Insect pests are a primary concern because there is no integrated pest management (IPM) program developed for these farms, and a common response to insects is to hand spray crops with broad spectrum insecticides as soon as insects are observed, without regard to pest density or damage. The initial purpose of this project was to develop sustainable and safe IPM programs by identifying insect pests and their natural enemies over the seasons of annual crop rotations, developing sampling tools and programs, and identifying control options for key insect pests such as targeted insecticide uses and sustainable practices (e.g., natural enemy release) to replace broad-spectrum insecticides.

The expansion of the Southeast Asian farming community has largely occurred without the benefit of developed IPM programs, and many farmers rely on older broad-spectrum insecticides. Although total acreage of Southeast Asian farms is relatively small (approximately 25,000 acres), the number of farms is large (approximately 5,400, with 1,500 in Fresno County). Farms are often worked by hand by many family members and extended family members are connected to individual farms. The development of an IPM program may reduce the overuse of broad-spectrum insecticides, improving environmental quality and food safety for these farming families. Many Southeast Asian farmers are immigrants and refugees. Most are tenants on rented land, and average farm income is $20,000 to $30,000 per year. Farming was often their original livelihood; however, not all of their traditional farming practices are economically or environmentally viable in California. Language barriers make information on pest management difficult for them to obtain. IPM tools made available with translations will provide these farmers with needed information and skills to grow their operations.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Project staff completed field sampling to assess arthropod communities and pest damage on Asian specialty vegetables in Southeast Asian farms in Fresno County. A total of 168 samplings were conducted on 24 different crops (representing eight plant families) in seven farms. A total of 36,065 individual arthropods were collected, identified, and classified into one of four functional groups (detritivores, herbivores, pollinators, and predators). Key pest species and natural enemies have been identified, data analysis has been completed, and community structure and similarity among different crops have been determined. This has generated a large baseline dataset on pest and natural enemy (beneficial insect) abundance in multiple crops over several seasons of crop rotations.

Sticky card traps were used to monitor the patterns of population colonization and dispersal of three key pest species (aphids, whiteflies and leafhoppers) commonly associated with three crops (eggplant, squash and tomato) at five farms in 2017. The abundance of these key pests and their damage to the crops were also monitored at these each sticky card monitoring site. Project staff simultaneously sampled plants to estimate the density of these pests and plant damage (rating from 0-3). Project staff modeled the sampling distributions for each of the three key pests using Taylor's Power Law, which indicates a uniform, random, or aggregated distribution. Project staff developed fixed precision sequential sampling models using Green's method to calculate optimal sampling size based on counting insects over a given number of samples. These models can determine action thresholds for insecticide treatment by relating the pest population density to observed plant damage. These sampling plans have been developed, and still need to be verified with independent data.

Field trials were conducted at the Kearney Agricultural Research and Extension Center (KARE) in Parlier, California in response to feedback from the Southeast Asian farming community to better understand basic pest behavior and ecology and evaluate potential pest control methods. In 2016, a trial was conducted on eggplant to quantify damage on both plants and fruits when exposed to four common pest insects (lygus, stink bugs, whiteflies, and aphids). Plants were caged in order to control insect species present and their abundance. A second trial in 2016, examined how presence and absence of weeds affect abundance of pest and beneficial insects in luffa squash and cucumber. In 2017, a field trial compared four insecticide treatments for efficacy in controlling aphids on commonly cultivated squash crops. These included one insecticide currently used by Southeast Asian farmers (Asana) and three reduced-risk insecticide treatments (Pyganic+M-Pede, Venerate, and Belay).

In early interviews and discussions with Southeast Asian farmers, participants indicated that an unknown disease of Asian yardlong beans (long bean or asparagus bean, *Vigna unguiculata* subsp. *sesquipedalis*) was of high importance. This disease causes foaming symptoms and usually appears on yardlong bean plants around June. The sticky foam appears to reduce yield and vigor, and it damages beans so that they are unsaleable. Neither the causal agent nor the mode of transmission is known. In 2016, project staff conducted a field trial to evaluate the mode of transmission. Based on farmer observations and perceptions, project staff evaluated the California fig beetle (*Cotinis mutabilis)* as a vector and compared three different methods of harvesting fresh beans for their effect on disease transmission. In this trial, long bean plants did not display any disease symptoms and project staff were unable to determine the mode of transmission. In 2017, three strains of microorganisms were isolated from the foam present on long bean plants. These strains were used to inoculate long bean plants cultivated in a greenhouse. Plants were inoculated with the individual strains as well as combinations of two strains and all three strains. However, inoculated plants did not display foaming symptoms. Project staff also conducted sampling of foaming disease incidence in farmers' long bean plots on two farms on four sampling dates. The total number of long bean plant nodes showing foaming symptoms was recorded in a grid sampling pattern to examine spatial patterns and dispersal of foaming symptoms. Long bean plots were divided into quadrants North East (NE), North West (NW), South East (SE), and South West (SW). The numbers of nodes infested with the disease were compared among the four plots for each field and each sampling date, respectively. The index of dispersion (variance divided by mean) was calculated for each plot, and the significance of index values was evaluated with a t-test.

Interviews and discussions with farmers identified pests of importance on Southeast Asian farms and pesticides commonly used for pest control. Based on interviews, focus group discussions, additional informal conversations with farmers, and input from the Fresno County Agricultural Commissioner's Office, project

staff identified pesticides commonly used by Southeast Asian specialty vegetable growers. Project staff identified a need for increased training on pesticide safety and legal compliance for Southeast Asian farmers in addition to adoption of improved IPM methods. As a result, educational materials and extension presentations included information on pesticide safety and understanding legal requirements for pesticide applications.

A total of 10 extension meetings were conducted, with a total of 334 attendees. These included a tour of a farm with demonstrations of natural enemy releases and the use of hedgerows for natural enemy habitat. Additional outreach was conducted at the Hmong New Year celebration in December 2017. An estimated 960 members of the Hmong community visited the educational booth with demonstrations of live insects and distribution of educational materials. Extension meetings included interactive demonstrations and activities with live and preserved insect specimens. Radio broadcasts extended project information and promoted events. Printed materials, online resources, and videos were developed on pest management topics including identification of beneficial insects, use of sticky traps, aphid management, correct application of pesticide rates through proper calibration and nozzle selection, and pesticide safety and regulatory compliance (see section below on target goals).

This project did not benefit any commodities other than specialty crops.

There were two main project partners, the University of California Cooperative Extension (UCCE), Fresno County and the University of California, Berkeley (UC Berkeley).

UCCE, Fresno County
The PI conducted farmer interviews and focus group discussions, assisted in identification of farms to sample, collaborated in planning of field trials, coordinated sampling of foam disease symptoms on long bean, conducted preliminary analysis of pest and beneficial insect samples, and coordinated and supervised all outreach and extension activities.

The Graduate Student assisted with development of educational materials on pest and beneficial insect identification and pesticide legal requirements, organized the database of pest photos, prepared insect specimens for educational demonstrations, conducted data entry, assisted with video filming, and collaborated on presentations at extension meetings.

The Staff Research Associate II assisted with coordination of extension meetings, purchasing supplies, photographing pests present on Southeast Asian crops and developing a database of pest photos to be used in preparation of educational materials, coordination of video equipment and filming, and preparing educational outreach materials on pesticide safety and legal compliance.

The Community Education Specialist (CES) I assisted with video filming, coordination of extension meetings, field sampling, data entry, outreach to farmers, and purchasing supplies. The CES I researched pesticide labels, conducted data entry to generate a database of pesticides registered on selected specialty Asian vegetables in California, and prepared educational summary sheets on pesticides commonly used by Southeast Asian specialty vegetable and strawberry growers.

The Laboratory Assistant I assisted with preparation and sampling in field trials, provided Hmong translation and assisted with demonstrations at extension meetings, coordinated video editing of recorded presentation material for public viewing in both Hmong and English languages, and assisted with farmer interviews and discussions with farmers in Hmong and radio programming in Hmong.

A CES II (Hmong Agricultural Assistant) contributed in-kind support to this project in addition to the employees paid on the grant. The CES II facilitated contact with growers and obtained permission to sample for pests on farms, provided radio broadcasting outreach, assisted with farmer interviews, facilitated discussions of major insect pests affecting Southeast Asian farms, provided translation of documents into Hmong, gave presentations at extension meetings, and assisted with field sampling.

UC Berkeley
The Co-PI oversaw data collection and sampling and coordinated planning of field trials on both Southeast Asian farms and experimental plots at the Kearney Agricultural Research and Extension Center.

The Laboratory Assistants and Student Assistants conducted surveys and insect identification, field trials, and data analyses. In 2017, early findings from the project were presented at various entomological workshops and conferences.

The Associate Specialist conducted analyses on pest and beneficial insect sampling data, pest damage data, sticky card trap catch data, insect community composition, and long bean foam incidence data.

The Postdoctoral Scholar assisted with outreach and presentations at extension meetings.

The Staff Research Associate II conducted filming and video editing of presentations at extension meetings and provided consultation on development of extension videos.

Goals and Outcomes Achieved

Sampling of pest and beneficial insects and pest damage was completed on seven Southeast Asian farms, generating a large dataset of insect species present on multiple crops and their abundance over several seasons for analysis with respect to insect pest damage on crops. Data analysis was completed to identify patterns in insect community structure among crops and seasons and factors affecting pest damage. Preliminary sampling plans were developed that can be field tested. At the last two extension meetings of the project, farmers were asked to complete an anonymous evaluation form to indicate their knowledge of topics covered in extension meetings before and after extension presentations, and their intent to adopt improved pest management practices. Changes in knowledge were reported using a pre- and post-questionnaire on a scale from 0-5, with 0 indicating no knowledge and 5 indicating a high level of knowledge. Intent to adopt was also reported on a scale from 0-5, with 0 indicating no intention of adoption and 5 indicating a strong intent to adopt.

Expected long term outcome measures included generating baseline data to inform future development and implementation of IPM programs in Southeast Asian farms and identifying new areas of research for graduate work in these farms. The project proposal noted that development and implementation of complete IPM programs would be likely to require more than three years, since little information was already available. Project staff have generated a large dataset of pests and beneficial insects on multiple crops through several seasons of crop rotation that can be further analyzed and used to understand pest dynamics on these

diversified farms. Project staff have also generated a database of pesticides registered on Southeast Asian specialty crops that will be used in future extension efforts. Areas for future graduate research include: 1) further research to identify the causal agent and mode of transmission of the foaming disease on Asian yardlong bean; and 2) landscape level studies with multiple farms to better understand the movement of pests among multiple crops with staggered planting dates and weeds present on farms.

Project goals included the following measurable outcomes:

1) Increase attendance at extension meetings from 75-100 farmers per year (15-20 per meeting) to 120-300 farmers per year (30-50 per meeting). Project staff did see an increase in attendance at extension meetings with an average attendance of 33.4 farmers, for a total of 334 farmers served through extension meetings. Additionally, an estimated 960 members of the Hmong community, including farmers and their extended family members, visited the educational booth at the Hmong New Year celebration.

2) Deliver 24-32 radio broadcasts per year. Radio broadcasts were used to deliver information on pest management topics, update farmers on the progress of research projects, answer questions on pest management during call-in periods, and advertise upcoming extension meetings. These topics were included in over 32 broadcasts per year.

3) Produce 2-3 educational pamphlets or booklets per year. A total of 26 educational pamphlets with Hmong translation were produced. These include a guide to identification of natural enemies, a guide to identifying pests on yellow sticky cards, a guide to aphid management, instructions for downloading pesticide labels, guidelines for field posting of signs after pesticide applications, and 21 two-page brochures summarizing important pesticide label information. The pesticide label brochures and instructions for pesticide labels were also printed in a binder for distribution to farmers. These materials are also available online on the UCCE Small Farms and Specialty Crops website for Fresno County. Links to relevant IPM guidelines available for vegetable crops grown by Southeast Asian farmers have also been added to the website.

4) Produce 2-3 instructional videos per year. Rather than produce multiple short videos, project staff decided to produce two longer educational videos giving more in-depth explanation of a topic. This also allowed project staff to stay within the budget allocated for video editing and production from the communications department. Also, one extension presentation was recorded and is available as a video online.

5) Goals for IPM programs and pest sampling included a target 10 to 20 percent change in any of the following outcomes: changes in insecticide use from more toxic to more sustainable insecticides, reduction in pest damage to the crop, and increase in the sale of organic or sustainably produced fruits and vegetables. Of these outcomes, project staff were able to document farmer intent to adopt more sustainable, less toxic, reduced-risk insecticides (average of 4.42 out of 5 on a 0-5 scale, with 5 being a strong intent to adopt) (see Table 2 below).

Based on calculations of species richness, diversity, and evenness, project staff found that crops from the same plant family and grown during the same season had similar insect communities. This indicates that grouping crops according to plant family and season could simplify pest management recommendations on highly diversified farms. Project staff also found a large amount of variation in the relationship between insect community composition and crop damage. Some crops, such as yardlong bean, had a relationship between

crop damage and pest insect species richness and diversity, and others had little to no pest damage, such as luffa and bittermelon. All regression analyses showed an aggregated distribution of pests on sticky card traps. Plant damage was positively related to the weighted pest density for aphids, whiteflies, and leafhoppers on eggplant, tomato, and squash. The sticky card data showed similar patterns of colonization and dispersal by adult aphids, whiteflies or leafhoppers on the three different crops across all five farms. At each farm, captured abundance of each pest in each crop plot was low at the early plant-growing stages, increased with plant growth, and then decreased at the end of pant-growing stage (or after the harvest of the plant). Project staff observed movement of these pests to eggplant after squash and tomato plants were harvested.

Only treatment with Belay significantly reduced aphid density, while aphid populations after treatment with the other three insecticides were not different than the control. While this study provides a preliminary indication that Belay is an effective reduced-risk insecticide on these crops, it requires replication in subsequent years and on farmers' fields in order to make accurate recommendations for the use of these insecticides for aphid control. No differences in insect densities were found between crops with weeds and crops without weeds; however, the presence of weeds was associated with higher levels of insect damage on both luffa and cucumber plants. This indicates that weed management could influence insect pest populations on diversified farms and highlights the importance of including weeds in sampling in order to understand pest dynamics.

Incidence of foaming symptoms was significantly higher on the east sides of long bean plots compared to the west sides. Numbers of nodes with symptoms were highest on samples collected from the NE quadrant of the field and lowest from samples collected on the SW quadrant (Figure 1). In each plot, the dispersion of the disease was random when the density was low but became aggregated with increased density, indicting a random-aggregation dispersion pattern. While aggregated dispersion would indicate a biological vector of the foaming disease, the random dispersion at low densities suggests that an abiotic mode of transmission is involved, followed by spreading of symptoms at initial infection sites. Project staff also observed anecdotally in multiple farms that incidence of foaming symptoms was more severe in the dark green varieties of yardlong beans compared to white (light green) and purple varieties. In one farm sampled, white long bean had a much lower incidence of foaming symptoms than dark green long beans on the same farm (Figure 1). In summary, this preliminary work has isolated three potential causal agents that could be tested further to determine the cause of the foaming disease, identified spatial patterns that could assist in evaluating the mode of transmission, and observed differences among varieties in susceptibility to the disease.

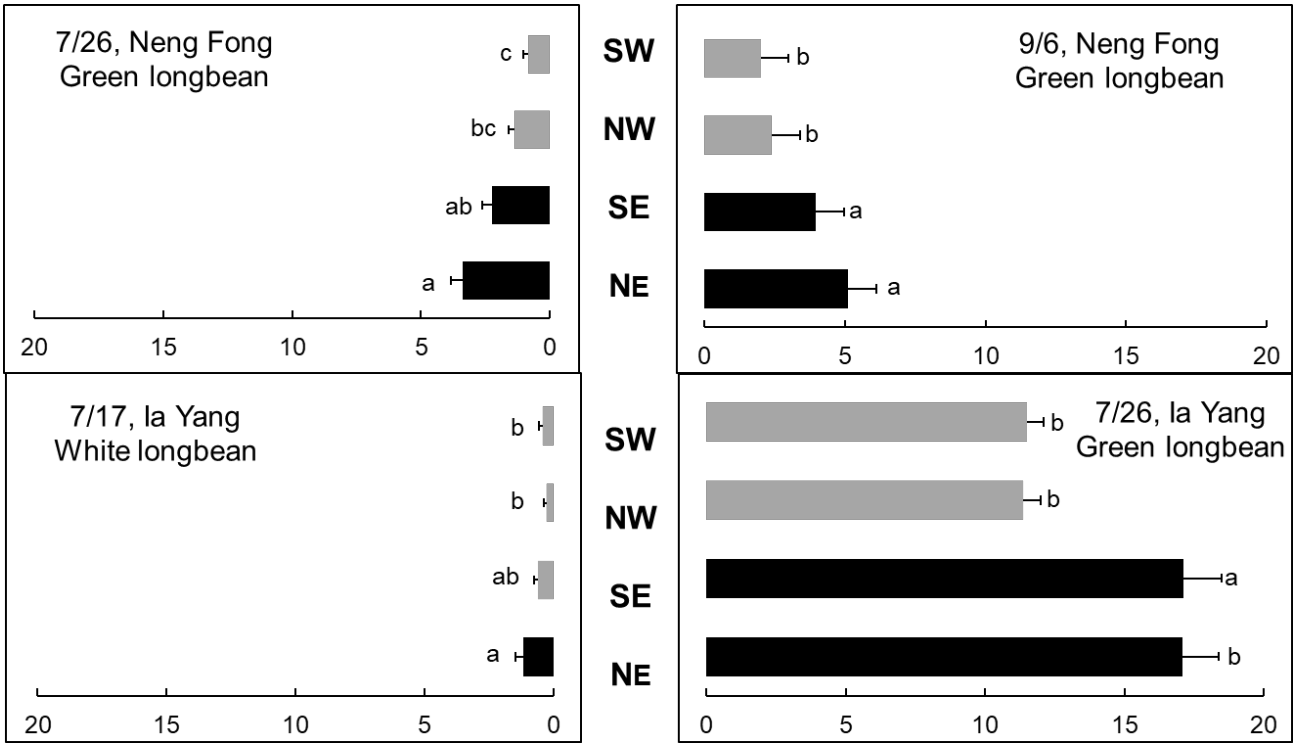

Figure 1. Within-field distributions of "Foam disease" in two different fields and on two different sampling dates. Bars accompanied by different letters are significantly different ($P < 0.05$) based on a one-way ANOVA with mean separation for compass direction by Tukey tests. Dark bars indicate the aggregation distribution while gray bars indicate random distribution.

Farmer attendance at extension meetings increased from 15-20 per meeting before the project to an average of 33.4 per meeting. Percentage increases in farmer knowledge on pest management topics covered in presentations at extension meetings ranged from 24.4 to 100.3 percent (Table 1). Project staff assume that the highest increases in knowledge were on topics that farmers had little knowledge of before the extension meetings. For example, the lowest increase in knowledge (24.4 percent) was on personal protective equipment, where farmers reported a higher level of knowledge before the meetings. The highest increases in knowledge (over 70 percent increase) were on the use of hedgerows and beneficial insects (93.6 to 100.3 percent increase) and backpack sprayer nozzle selection (84.6 percent) and calibration (74.8 percent). Farmers also indicated a strong intent to adopt several improved pest management practices covered in extension meetings (Table 2). Quantities of educational materials produced and distributed to farmers both at extension meetings and online are described above in relation to targets for established goals. Ten extension meetings were held, and additional outreach was conducted with an educational booth at the Hmong New Year celebration. Project staff identified 21 pesticides commonly used by Southeast Asian farmers and 17 pests of major importance in their farms through interviews and discussions. Four presentations by project partners were made at professional society meetings. A baseline dataset of insect pests and beneficial (natural enemy) insects present on 24 crops grown in Southeast Asian polycultures was generated that can be used to inform future research. Relationships between insect pest populations and insect damage were quantified and analyzed with regard to individual pests and insect community composition on each crop. Sampling plans were developed based on yellow sticky card trap catches for three important pests (aphids, whiteflies, and

leafhoppers) on three typical crops (eggplant, tomato, and squash). Three field trials increased knowledge of pest ecology and behavior on eggplant, luffa squash, and cucumber. Three isolates of microorganisms present in the foaming disease of yardlong bean were cultured and can be used in future studies.

Table 1: Changes in Farmer Knowledge on Pest Management Topics

Meeting and Topic	Percent increase in farmer knowledge
Plants to Use in Hedgerows	100.3
How to Release Beneficial Insects	95.0
Where to Buy Beneficial Insects	93.6
Selecting the Right Nozzle	84.6
How to Calibrate a Sprayer	74.8
How to Identify Insects	66.3
Predators and Parasitoids	62.3
Pesticide Use Reporting	61.7
How to Attract Beneficial Insects	57.6
Pesticide Label Requirements	49.4
Personal Protective Equipment	24.4

Table 2: Intent to Adopt Improved Pest Management Practices

Pest Management Practice	Average score on 0 – 5 scale
Calibrate the sprayer to use the correct rate	4.71
Use the correct nozzle to avoid drift	4.53
Monitor pests to only spray when needed	4.44
Using less toxic pesticides	4.42
Avoid spraying beneficial insects	3.94
Releasing beneficial insects	3.67
Planting a hedgerow to attract beneficial insects	3.50
Applying for the NRCS-EQIP cost share to plant a hedgerow	3.50

Beneficiaries

The main group that benefited from this project was the Southeast Asian farmers of Fresno County and surrounding counties. This group includes Hmong, Mien, Lao, Thai, Cambodian, and other Southeast Asian immigrant farmers growing specialty vegetables, herbs, and strawberries. This project also benefited the Fresno County Agricultural Commissioner's Office through increasing outreach and educational efforts to Southeast Asian farmers on legal compliance for pesticide use.

This project benefited a total of 334 Southeast Asian farmers attending extension meetings, an estimated 960 members of the Southeast Asian community attending the Hmong New Year outreach booth, and an unknown number of Southeast Asian farmers from Bakersfield to Modesto listening to radio broadcasts.

Lessons Learned

Project staff were able to attract a larger number of farmers per extension meeting as a result of outreach activities on this project. Extension meetings on pest management through UCCE in Fresno County prior to

the start of this project attracted 15-20 farmers per meeting. Through increased outreach, attendance increased to an average of about 33 farmers per meeting. Printing flyers for meetings and posting them in stores frequently visited by Hmong farmers, such as specialty Southeast Asian grocery stores and agricultural supply stores, seemed to be particularly effective in reaching farmers not previously familiar with the extension program.

Developing IPM programs in which the decision to treat a crop or not is based on insect sampling was more difficult than anticipated due to the large diversity of crops in Southeast Asian polycultures and the uneven, staggered planting dates to ensure continuous harvest over a season. These factors made typical methods of insect sampling difficult and made pest monitoring more complex, as pests can move from one crop to another crop and from an earlier planted crop to a later planting of the same crop. As a result, project staff decided to use a D-Vac suction machine to sample all insects present on selected crops. Project staff also decided to use yellow sticky card traps for monitoring pest presence or absence rather than sampling methods that would rely on counting numbers of insects per plant. This simpler method is more appropriate for highly diverse polycultures.

Farmers had a higher level of interest in biological control than project staff had originally assumed. After an extension meeting on biological control with demonstrations of live insects, some farmers asked to visit a farm implementing biological control with releases of natural enemies. As a result, project staff modified the extension activities to include a tour of a farm with demonstrations of natural enemy releases such as lacewings and parasitoid wasps and the use of hedgerows to provide habitat for natural enemies. Also, the feedback received from visitors at the educational outreach booth during the Hmong New Year was unexpected. Visitors indicated that the project's booth was the only educational booth with interactive activities and expressed appreciation for the educational demonstrations. This was especially attractive for parents with younger children, and it seems to be an effective way to reach a larger audience of farmers as well as the wider Hmong community with information on pest management.

The large diversity of crops and planting dates made the analysis of the project's insect sampling and damage data more complex than originally anticipated, and this affected the project staff's ability to prepare peer-reviewed publications within the time frame of the project. Future studies would benefit from an experimental design that focuses on a few variables to eliminate variation from other sources, such as studying one pest at a time on multiple crops or multiple pests on one crop. In order to better understand the abundance and movement of pest populations in complex polycultures, a more comprehensive study would be necessary that could measure multiple variables such as crop variety, planting date, area, and landscape context across a larger number of farms. While farmers shared clear information on the pesticides they use for individual pests, their opinions on the effectiveness of control methods currently in use were difficult to determine through translated interviews and group discussions. Since most comments on the effectiveness of control methods were unclear or vague, project staff did not include them in their analysis. More in-depth interviews would be necessary in order to determine farmer perceptions of the efficacy of individual pesticides on specific pests.

Additional Information

The following website is targeted towards Hmong and other Southeast Asian farmers with information on pest management. It contains the educational materials developed by this project as well as previously developed handouts and other educational materials:
http://ucanr.edu/hmonginfo

Presentations at an extension meeting by UC Berkeley project partners can be seen here:
https://www.youtube.com/watch?v=5Q316Iqwy_Y&feature=youtu.be

Tour of habitat for beneficial insects and viewing of insect specimens at the farm:

Extension meeting on June 6, 2018 and viewing of insect pests on samples of crops:

Outreach booth at the Hmong New Year celebration:

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 58	**Project Title:** Determining the Effects of Limited and Poor Quality Irrigation Water on Weed Composition and Control in California Tree Nut Crops	
Grant Recipient: The Regents of the University of California, Davis	**Grant Agreement No.:** SCB15058	**Date Submitted:** December 2018
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Project Summary

This project was conceived in 2014 amid a drought that was later characterized as the driest since record keeping began in the state of California. During the decades leading up to this period, the tree nut industry had increased dramatically in the Central Valley. Unlike annual crops, which can be fallowed in times of drought, tree nuts must be actively maintained and adequately irrigated to ensure harvestable yields for decades. The historic drought resulted in curtailment of water deliveries from many of the State and Federal water projects. Limited fresh-water availability, lead many tree nut growers to depend even more heavily on ground water to meet their irrigation needs. Ground water may be of poor quality due to mineral (e.g. calcium, sodium, chlorine, boron, and selenium) accumulation. Research has been conducted to identify crops and/or cultivars tolerant to drought and salt contamination. The effects of the same stressful growing conditions on weeds, which compete with crops for an inadequate water supply; however, have not been similarly explored to any significant degree in California. One goal of this work was to explore the effects of how soil, water, salinity, and pH interactions and drought-related stresses affected weed community composition and control in perennial cropping systems. A second research goal was to evaluate direct interactions of saline soils and saline irrigation water on the leaching potential of several preemergence herbicides commonly used in tree crops. Ultimately, these data as well as allied research at the Regents of the University of California, Davis formed the basis of knowledge for answering specialty crop grower questions and disseminated through the cooperative extension outreach programs.

The historic drought of 2011-2017 was the driver for this work that began in late 2015 with grower and tree nut industry surveys and continued with laboratory and greenhouse research through mid-2018. Although the drought, which was the impetus for the research, ended during the project, the underlying challenges of insufficient irrigation water quantity and quality will undoubtedly remain an issue in the future. This is particularly the case in the southern San Joaquin Valley due to saline soils, poor quality ground water, and high evapotranspiration rates. In addition to the drought-related factors driving this research, concerns have been raised about whether irrigation water additives such as fertilizers, pH modifiers, de-scalers, and pesticides affect soil-applied herbicides. The soil affinity and/or degradation processes of many herbicides can be affected by pH and ions/cations in the soil and it is not known how or if poor quality or heavily-amended irrigation water interacts with these important weed control tools. Unforeseen differences in mobility or dissipation can directly impact weed control performance, orchard crop safety, and potentially environmental quality. This research provided information to the California specialty crop industry about selective forces on weed populations of irrigation water quality and how irrigation water parameters impacted herbicide fate in tree nut orchards.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The overall tasks that were performed through the course of the grant were as follows:

- Evaluation of literature, available data, and grower experience related to weed management under drought conditions in orchard crops.
- Growth chamber research was conducted to evaluate the effects of various salts on the germination and establishment of important orchard weeds.
- Laboratory research was conducted to evaluate the effects of saline irrigation water on orchard herbicides in the soil environment.
- Outreach to growers, commodity representatives, pest control advisors, and others was conducted to share weed control strategies and mitigation strategies for any negative impacts of climate conditions on weed management in California orchard production systems.

This project focused on weeds, herbicides, and soil/water issues primarily relevant to California tree nut production systems. The project investigator's overall program had a primary focus on tree and vine crops with a secondary focus on minor acreage vegetable and seed crops; thus, this project benefitted only specialty crops in California. All grant funds were tracked to ensure that grant funds were solely used to enhance the competitiveness of specialty crops.

The principal investigator and co-principal investigator on the project, developed the original project plan together. The co-principal investigator conducted the initial surveys, literature reviews, and seed germination assays. When the co-principal investigator left the Regents of the University of California, Davis in December 2016, they continued to provide some oversight of the weed biology aspects of the project. The ongoing work however, was conducted by undergraduate laboratory assistants supervised by the principal investigator. A PhD graduate student was hired, whom developed procedures and conducted the analytical chemistry aspects of the project. The principal investigator, co-principal investigator, PhD and MS graduate students were responsible for preparing the scientific manuscripts. Lastly, the principal investigator had primary responsibility for extending this information to California specialty crop producers through his statewide Cooperative Extension program.

Goals and Outcomes Achieved

The tasks performed in order to achieve the performance goals and measurable outcomes were as follows:

- The project team reviewed literature on the effects of drought stress on weed communities in irrigated agricultural systems. The team also reviewed the California Department of Pesticide Regulation, Pesticide Use Reporting data to understand whether there were apparent drought-related trends in orchard herbicide use.
- Investigators engaged in discussions with research and extension personnel within California as well as other states in the arid West about observations on to drought-related weed shifts.
- While participating in extension meetings around the state, principal investigator and co-principal investigator interacted with California specialty crop growers whom shared their observations about weed shifts and other weed management issues, such as herbicide failures, suspected to be related to the ongoing drought.

- The co-principal investigator developed protocols for evaluating the effects of various salts on the germination of several key orchard weed species. Over the course of the performance period, the co-principal investigator and later a series of laboratory assistants, conducted over 60 individual replicated experiments to determine the relative sensitivity/tolerance of six weed species (Palmer amaranth, redroot pigweed, common purslane, junglerice (two biotypes), and three spike goosegrass) to six salts (MgCl2, CaCl2, KCl, NaCl, KNO3, and NaNO3).
- A series of preliminary studies were conducted to evaluate the effects of saline irrigation water on leaching potential of several key orchard herbicides. The project team originally intended to use bioassay techniques, but later revised to use analytical chemistry techniques instead.
- The graduate student researcher who joined the team midway through the project conducted approximately 20 experiments in the laboratory to evaluate the effects of simulated saline irrigation water on the leaching potential of four herbicides in two orchard soils. This approach utilized a water extraction technique to approximate the amount of herbicide in the soil solution versus adsorbed to soil which was directly related to the amount available for leaching or crop exposure.
- Throughout the project period, both the principal investigator and the co-principal investigator interacted regularly with California specialty crop growers to share information from this project as well as more generally help address weed management issues in orchards, vineyards, and other fruit and nut crops. The project team delivered over 100 presentations at meetings or grower field days reaching approximately 5,000 stakeholders during the performance period of this project.
- Data from this project was presented at three scientific conferences with approximately 300 attendees. Preparation began on two manuscripts to be submitted to peer-reviewed scientific journals (one on seed germination, one on herbicide analyses in soil).

California specialty crop producers will always have to manage weeds to ensure productive, safe, and healthy foods. This research originally focused on the immediate issue of drought and reduced deliveries of high quality surface irrigation waters, but the long-term value of the data and the expertise developed during the project period will continue to have benefit to the specialty crop growers.

Project goals relative to accomplishments were as follows:

- Goal 1a: Describe several important drought/salt tolerant weed species and collect baseline data on relevant weed issues through conversations with stakeholders and colleagues. This was largely accomplished.
- Goal 1b: Conduct a series of studies on soil water quantity and quality on weed germination. The water quality aspects (salts) was accomplished. However, the water quantity aspect which was to be evaluated using a gradient of osmotic stress was not fully achieved because the project team was unable to provide a sufficiently broad range of stress conditions with the polyethylene glycol solutions as was originally anticipated. Although the project team plans to follow-up with a later experiment on at least one relevant species, it was not achieved during the reporting period.
- Goal 2a: Evaluation of pesticide use reporting databases and discussion with stakeholders and experts on trends in weed control practices as impacted by the drought. This was largely accomplished as proposed.
- Goal 2b: Determine how weed control would be affected by changes in water quantity and quality. After many conversations with the specialty crop industry, it was determined that in spite of the drought, water quantity was not typically the limiting factor in specialty crops because of their value

(the crop is usually either irrigated, or it is removed if not feasible or economic to irrigate, but they are not often under-irrigated). This goal shifted towards using analytical chemistry approaches to compare the availability of several important orchard herbicides (saflufenacil, indaziflam, rimsulfuron, penoxsulam) in two soils (sandy versus clay loam) under a range of saline water conditions. Although rimsulfuron was initially tested, it was determined that the data were biased by an artifact of the extraction method used; thus no rimsulfuron data were presented. Although the specific focus changed, the underlying objective of this goal was largely met by the end of the project period and will be completed soon using supplementary funding from the specialty crop industry. Additionally, this component of the project has led to some new areas of research that will be explored further in future projects that will also benefit the California specialty crop industries.

- Goal 3: Increase knowledge of the impacts of drought on weed management in specialty crops. The project team's knowledge certainly increased, and this baseline knowledge will undoubtedly have long term benefits with regards to helping growers respond to shifting weed management challenges in the state. This knowledge was also shared with other specialty crop growers.

A few representative baseline data are presented below align with a very brief synopsis:

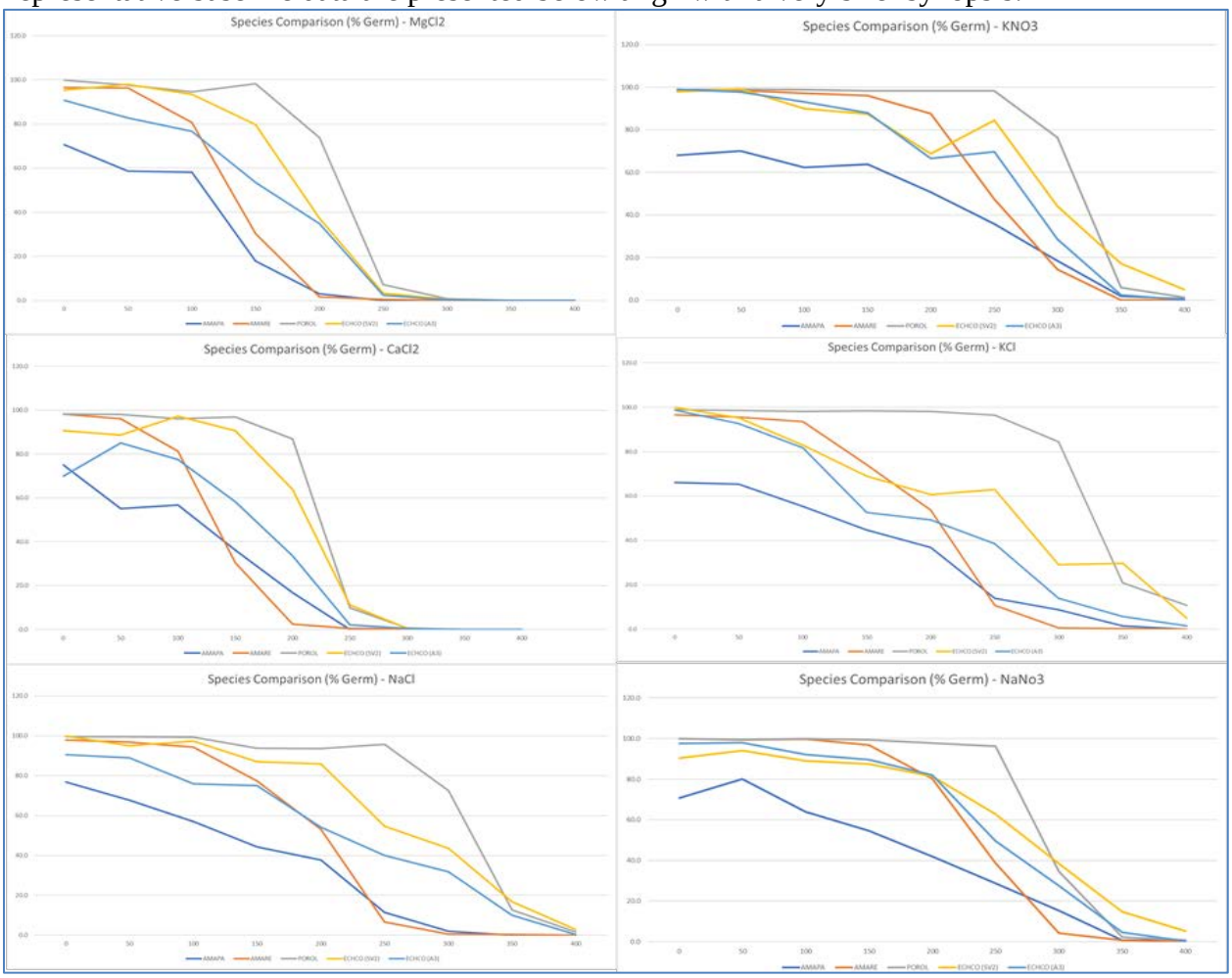

Figure 1: Effect of salt concentration on germination of five orchard weeds.

Each species-salt concentration was conducted as a separate experiment and data were developed with daily observations of germination from 50 seed per petri dish. Each data point was the mean of three replicates and two experimental runs. The six panels in this Figure 1e represented specific salts and there were seven increasing concentrations to allow the development of response curves; however only mean data were presented here. Weed abbreviations: AMMAPA = Palmer amaranth, AMARE = redroot pigweed, POROL = common purslane, ECHCO(SV2) = glyphosate-resistant junglerice, and ECHCO(A3) = glyphosate-susceptible junglerice. Weed species such as common purslane were more tolerant of many salts and likely to increase under challenging conditions such as poor quality irrigation water. Interesting, the glyphosate-resistant junglerice population was more tolerant of most salts than the glyphosate susceptible population; however, it was not known whether this was due to the resistance trait directly or simply a co-evolved trait since the SV2 population was from the southern San Joaquin Valley while A3 was from the northern Sacramento Valley and would have had vastly different irrigation water regimes.

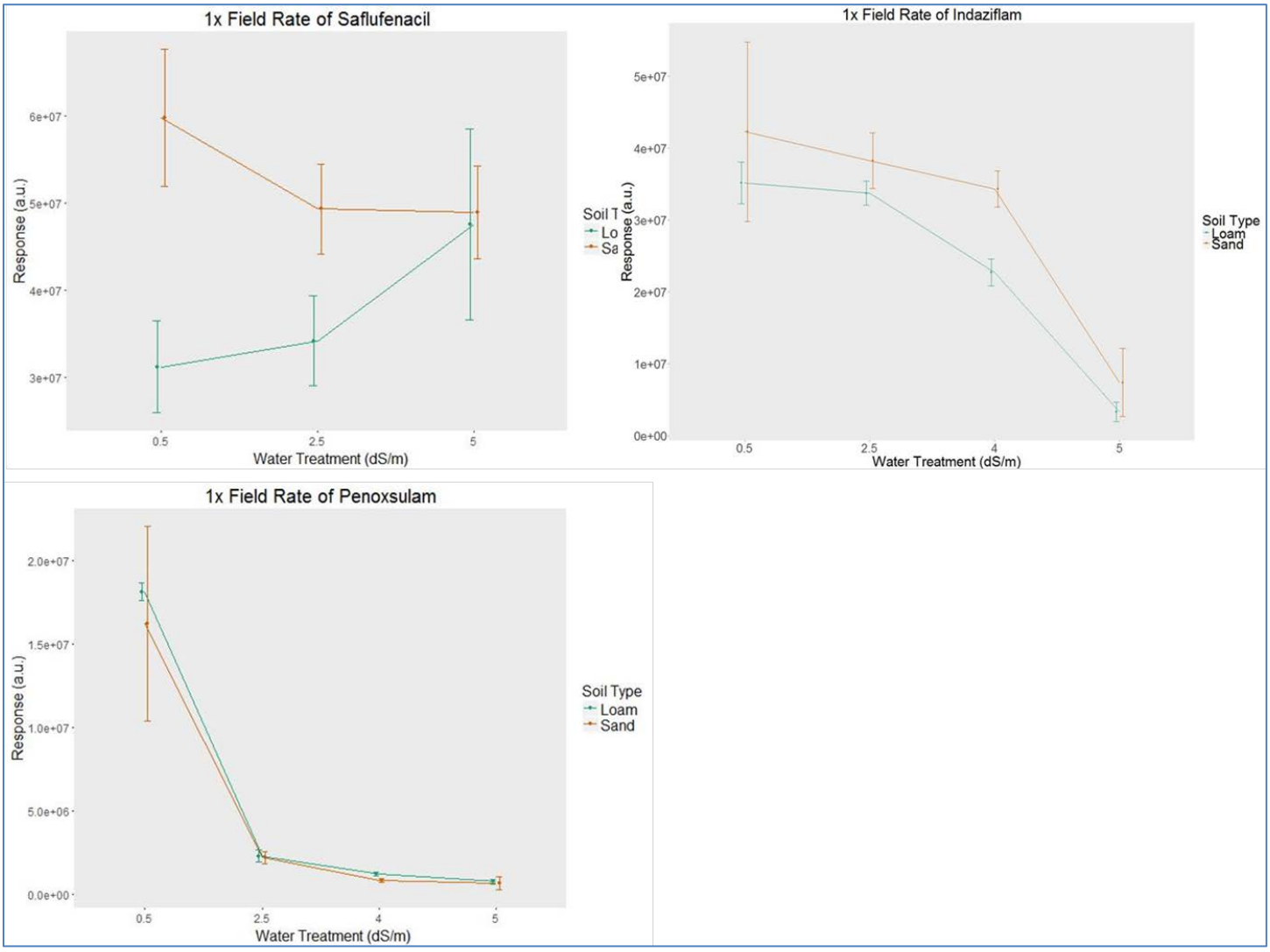

Figure 2: Partitioning of three orchard herbicides in soil as affected by salinity (dS/m) of the soil solution.

Saflufenacil (top left of Figure 2) partitioning was similar for the sand and loam soils at the highest electrical conductivity (EC) treatments but was higher in sand versus loam at the low EC. Indaziflam (upper right of Figure 2) partitioning decreased as soil solution EC increased in both soil types. Penoxsulam (lower left of Figure 2) partition was similar for the two soils, but decreased dramatically as EC increased.

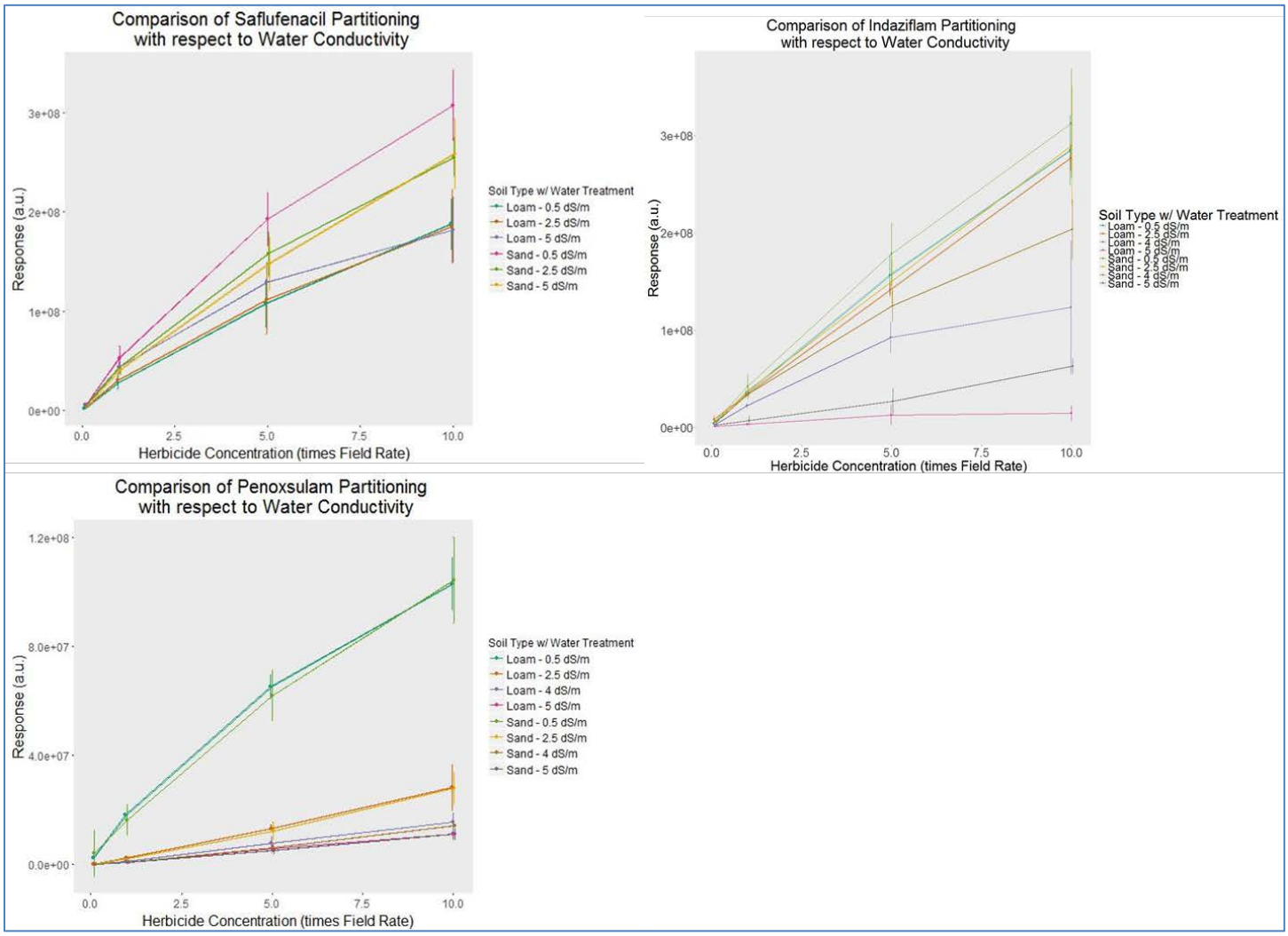

Figure 3: Partitioning of three orchard herbicides in soil.

In Figure 3, the x-axis is herbicide rate (1x, 5x, and 10x the nominal use rate) and lines represented combinations of soil type and water EC values. Generally, saflufenacil (top left) was more weakly bound to sand versus loam but was not strongly affected by soil EC. For indaziflam (top right), binding affinity was affected by both soil and soil water EC. Penoxsulam (lower left) was more dramatically affected by soil solution EC than by soil type.

Prior to the initiation of this project, there had been relatively little research on the combined effects of drought, poor-quality irrigation water, and weed germination in California specialty crops. Further, no information was previously available on how soil water conditions directly impacted herbicides used in

orchard crops. It was found that water quantity was not likely to vary sufficiently within the orchard production system to impose significant selection pressure that would lead to changing weed spectrums. However, irrigation water quality, particularly salinity, was likely to favor and disfavor different components of the weed population to some degree. Weeds such as common purslane which was relatively salt-tolerant could displace some more salt-sensitive species. Additionally, this research was among the first to directly assess the impacts of saline irrigation water on orchard herbicide binding affinity in California soils. Future work should be done in this area to determine if the difference observed in herbicide partitioning in orchard soils in lab assays corresponded to differences in weed control efficacy, orchard crop safety, or off-target movement of these pesticides.

Beneficiaries

The primary beneficiaries of this project were orchard and vineyard crops and their allied commodity groups and support industries in California. The project team focused on herbicides and weeds common to the tree nut production systems. The most direct benefit was to the almond, walnut, and pistachio producers with secondary benefit to other tree fruit growers who use many of the same weed control strategies and face similar weed challenges.

The goal of this project was to reach more than 30 percent of all tree crop growers with information about drought-related changes in weed management either directly through the University of California Cooperative Extension outlets or indirectly through the farm press and interactions with orchard crop industries and Pest Control Advisors. Industry statistics suggest that there are approximately 15,000 growers involved in nut production. Approximately 5,000 California specialty crop stakeholders benefitted from this project.

Lessons Learned

One lesson that was learned or reinforced during this project was the importance of maintaining flexibility to respond to opportunities (or dead ends) that were encountered during the research process. When a significant staff change occurred, the project focus was shifted from weed biology to having a greater emphasis on herbicide chemistry. Some facets of the research were changed as it became clear that the hypothesis was incorrect or the methods inappropriate or insufficient.

A second lesson was to consider how long each proposed experimental series would take and whether the project team and project budget could really support it. In this research, the project team grossly underestimated how long each of the seed germination experiments would take from setup to completion (mostly the setup and preliminary experiments) which put the project well behind schedule and ultimately contributed to dropping the seedling growth experiments that were originally proposed. Similarly, with the analytical chemistry experiments, it often took months of preliminary work to develop the techniques and apparatus to conduct what was ultimately only a several-day experiment.

Lastly, the budget was regularly revisited to ensure that spending was on track. It was important to re-budget in a timely manner since the grant duration was relatively short. For this project, early spending was slower than anticipated due to the relatively low cost of research supplies for the initial goals and due to the salary savings, that occurred when the co-principal investigator changed jobs. It also took more time to hire new project staff which meant that more spending occurred later in the performance period when the research was focused on the more expensive laboratory research.

Implementation of this project lead to several interesting or unexpected outcomes and opportunities. First, the analytical chemistry components suggested a very interesting interaction with soil water EC and the physical conformation of soil organic carbon. In the context of this project, that may have influenced how strongly the herbicides were binding to soil. It could also be relevant to other soil physical and biological parameters that influence specialty crop productivity and soil health parameters.

Also, in developing techniques, apparatus, and research team experience in soil-herbicide analyses, several tangential projects relating to how orchard herbicides behaved in soil and how these pesticides affected non-target organism such as soil microbial communities were found. This could lead to future opportunities to provide important and relevant information related to weed control strategies to the specialty crop industries in the state.

Although some specific goals were amended or deemphasized during the performance period, the overall goals of the project were largely achieved. Ultimately, the goal of this research was to help California tree nut growers address weed control issues and understand the interaction of weeds, soils, herbicides, and irrigation water. The project team intends to continue this theme beyond the timeline of this project with the intention to continue to support California specialty crop producers.

In addition to the research information developed during this project, another important ancillary benefit was the training and career deelopment of several project personnel who conducted or assisted with portions of the research. Partially as a result of their involvment in this work, several of them adjusted their career goals to include speciality crop agricultural research. For example, the co-principal investigator on the project took an interim position working on weed control in apple and cherry systems in Washington and has since returned to California for an academic positon with the University of California in Madera and Merced Counties. Two undergraduates who worked on the project have since been accepted into graduate programs in agricltural disciplines with the intentions of working in the unique crops of California. One of these student's thesis research will build directly on work started in this project. Finally, the graduate student who conducted the analytical chemistry aspects of the project developed a new passion and career interest related to pesticides and their interactions with specaility crops, the soil enviroment, and the soil micribial community. Although not a stated goal of this project, the influence funding from this program will have had on these future leaders of agricltural research should not be overlooked.

Additional Information

No additional information.

USDA Project No.: 59	**Project Title:** Identification of Novel Indicator Organisms to Determine the Risks of Fecal Contamination of Irrigation Waters	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB15059	**Date Submitted:** December 2018
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Project Summary

Bacterial indicators of fecal contamination, such as generic *Escherichia coli (E. coli)*, appear to be inadequate for estimating the occurrence and levels of microbial pathogens in irrigation waters. The standard methods used by the produce industry to detect *E. coli* in irrigation waters utilize techniques developed for drinking water, which have not undergone extensive scientific scrutiny; as such, these methods may not be wholly appropriate for determining the quality of irrigation waters. For instance, using standard methods such as the Colilert® MPN test (used by the produce industry to determine irrigation water quality), *E. coli* may be found in greater than or equal to 87.6 percent of samples. Nevertheless, the results of another Center for Produce Safety study (2011 Specialty Crop Block Grant Program Project 69: *Assessment of Escherichia coli as an Indicator of Microbial Quality of Irrigation Waters use for Produce*) indicated that standard methods, such as the Colilert® MPN and the MI agar and m-ColiBlue24® membrane filtration methods, had high false-positive rates (from 51 percent to 71 percent). False-positive results could have large implications of over-estimating the actual concentration of *E. coli* in a water sample. This could lead to costly interventions such as non-use of water, delayed irrigation, and product rejection. Also, the Food Safety Modernization Act (FSMA) Produce Safety Rule standards of less than or equal to126 *E. coli* per 100 ml for a geometric mean of 20 samples (a rolling dataset including the most recent 20 samples collected) or less than or equal to 410 *E. coli* per 100 ml as the statistical threshold value (STV) (90 percent of samples must fall below this level) have been used as arbitrary thresholds of risk for pathogen levels in irrigation water, for which there is little scientific basis. Based on the project team's previous sampling data, *E. coli* was detected at numbers above this threshold in only 2.6 percent of samples, whereas *E. coli* and *Salmonella* species could be detected via other cultural methods with greater frequencies (8.1 percent and 12.4 percent, respectively) (unpublished data). There is therefore a need to evaluate this threshold to see whether it can be correlated with the presence of foodborne pathogens. It is also important to identify novel indicator organisms that are present in water when microbial pathogens are present or to detect a shift in the microbial composition for their use as potential future methods to replace the use of generic *E. coli*.

The goal of this project was to improve the safety of irrigated food crops by identifying more appropriate indicator organisms or groups of organisms to determine the risks of contamination of crops by foodborne pathogens from irrigation water. The team's hypothesis was that next-generation DNA sequencing (NGS) could be used as an inexpensive and powerful method to identify the composition (presence and relative abundance) of the entire prokaryotic (bacterial) and eukaryotic (e.g., protozoan) microbial communities found in irrigation waters. Such information could then be used to correlate the presence of foodborne pathogens with either shifts in the community makeup (from that of un-impacted, non-contaminated waters) or with the presence of specific species (i.e., potential indicator organisms). High-throughput sequencing would parallelize the sequencing process, producing thousands or millions of sequences at once, which would reduce the costs and the time required. The Illumina MiSeq and HiSeq were NGS platforms that allowed for millions

of reads of 250 base-pair (bp) sequences and allowed for bi-directional sequencing, providing greater accuracy.

The methods used to detect *E. coli* were developed for drinking water and known to produce high levels of false-positive and false-negative results when used for irrigation waters. Therefore, requiring growers to make decisions about water quality and safety based on inaccurate tests. In the current project, the entire microbial compositions (the microbiome) of irrigation water samples from two different fresh produce growing regions in Arizona (Region One and Region Two) over a two-year period were determined using NGS microbiome analysis. Samples were collected from areas with historically higher and lower levels of contamination based on the results of previous studies. In addition, samples were collected from canals with various characteristics (e.g., main canals and lateral canals, cement-lined and non-lined canals, urban and rural canals, primary irrigation canals and return flow canals). Samples were also collected both during the winter leafy green growing season and during the summer to assess whether there were any seasonal influences on the microbial water quality. The microbial communities between samples that were positive and negative for the presence of pathogens were compared and analyzed to identify groups of organisms or specific species whose presence correlated well (both presence, absence, and relative abundance) with the occurrence of foodborne pathogens.

The presence of pathogens or shifts in the microbial communities were also compared to other water quality characteristics and potential impacts (e.g., rainfall, human and animal influences). The preliminary results of this work suggested that there were both significant regional and seasonal differences in the microbial populations found in irrigation waters. Therefore, it was important that the “normal” composition or “baseline” level of microorganisms be determined for each region before undertaking any such NGS evaluation of the effects of various contamination inputs. Nevertheless, once such baseline evaluations have been conducted, NGS can provide valuable information on any changes such inputs have on the microbial water quality. For instance, when samples were analyzed from areas with known impacts, such as those with historically higher levels of fecal contamination or from return flow (drainage) canals that collected run-off from agricultural fields, shifts in the predominant microbial populations were observed. This work should result in an approach that will provide region and/or season-specific identification of species or microbial population shifts, which may be used to identify changes in the microbial quality of specific irrigation water systems. This information would allow members of the fresh produce industry to make risk-based assessments of water quality and help to determine when it is safe to irrigate fields.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Key activities performed during the project were associated with Objective 1: Examine irrigation water samples to determine the levels of indicator (i.e., generic *E. coli*) and pathogenic (i.e., Shiga toxin-producing *E. coli* [STEC] and *Salmonella*) species by existing cultural and molecular methods, Objective 2: Examine irrigation water samples to determine the levels of viruses known to be found in high concentrations in fecally-contaminated waters (i.e., pepper mild mottle virus, Aichiviruses, and enteroviruses, Objective 3: Determine the composition (presence and relative abundance) of the entire prokaryotic (bacterial) and eukaryotic (e.g., protozoan, fungal, algal) microbial communities found in irrigation water samples, and Objective 4: Identify groups of organisms or specific species whose presence correlate well (both presence/absence and relative abundance) with the occurrence of foodborne pathogens in irrigation waters.

During this project, 99 irrigation water samples were collected in triplicate (for a total of 297 samples) from canals with various characteristics (e.g., main canals and lateral canals, cement-lined and non-lined canals, urban and rural canals) from two different fresh produce growing regions in Arizona. The growing season for leafy greens in these regions took place from approximately October through early April each year. Half of the irrigation water samples were collected during the growing season and half during the summer, over two years. Data collected from previous studies regarding the occurrence of fecal contamination and the presence of pathogens in the irrigation water canals in these regions were studied to ensure that areas with historically low contamination and higher contamination levels were included. After examination of the historical data, samples from a second region were also collected as part of this study though not initially included in the original proposal. The irrigation waters from this second region were typically of lower microbial quality than irrigation waters in the originally proposed region. Each triplicate "sample" consisted of the following grab samples: a 3 L sample, a 2 L sample, and a 1.1 L sample. Water quality parameters, such as the temperature, pH, electro-conductivity, and the amount of total dissolved solids, were recorded in the field. Other environmental parameters, such as the air temperature and relative humidity, were also recorded in the field at the time of sample collection. The samples were then brought back on ice to the University of Arizona for processing.

Upon arrival in the laboratory, the 1.1 L samples were evaluated for turbidity (cloudiness) as well as bacterial indicators and pathogens in separate tests. The Colilert MPN method was used to test for total coliforms and generic *E. coli* in the samples. In addition, these samples were tested for the presence of *Salmonella* species and *E. coli* after the concentration of 1 L using membrane filtration. The filter was then placed into an enrichment broth and incubated overnight to increase the bacterial numbers. This broth was then used to inoculate a series of selective media for the isolation and identification of *Salmonella* species and *E. coli*. For *Salmonella* species isolation, this procedure included tetrathionate broth, followed by Rappaport Vassiliadis broth, then followed by streaking for isolation onto xylose lysine deoxycholate agar plates. Presumptive *Salmonella* colonies (black centers) were sub-cultured onto CHROMagar Salmonella plates for further selection. Presumptive colonies on CHROMagar Salmonella plates (mauve color) were tested using API 20E biochemical test strips for confirmation of the species identification. For *E. coli* isolation, the procedure included the inoculation of *E. coli* broth from the original enriched culture and incubation at 44.5°C for 24 hours (or at 48 hours if negative after 24 hours). The tubes that exhibited both bacterial growth (turbidity) and the production of gas (bubbles collected in an inverted Durham tube) were subcultured onto eosin methylene blue agar plates with overnight incubation at 44.5°C. Presumptive *E. coli* colonies, (darkly pigmented, with or without a metallic sheen) were tested using API 20E biochemical test strips for confirmation of the species identification. The isolates that were confirmed as either *Salmonella* or *E. coli* using API 20E biochemical strips were tested using conventional polymerase chain reaction (PCR) for virulence genes (e.g., *stx1* and *stx2* Shiga toxin genes and the *eae* gene for *E. coli* and the *invA* gene for *Salmonella*).

A total of 8 of the 297 water samples (2.7 percent) were found to be positive for *Salmonella* species. These samples represented 6 of the 99 triplicate samples (6.1 percent). For all but one of the triplicate samples, *Salmonella* was detected in only one of the three enriched sample replicates. This finding suggested that *Salmonella* levels were very low in these samples. This conclusion was supported by the results of a recent study conducted in which *Salmonella* levels in irrigation waters from these two regions were found to be quite low (usually from 0.1 to 1.0 colony forming units (CFU) per 100 ml) (unpublished data); these levels would not be detected without an enrichment step. Depending upon the serovar, the infectious dose for *Salmonella* usually ranged between 10^5 and 10^{10} (100,000 to 10,000,000,000) bacteria, though this could be lower for the

elderly, the very young, and immunocompromised individuals (Kothary and Babu 2001), or in foods that protected *Salmonella* from the antimicrobial effect of stomach acids (Gama et al. 2012). Based on the low levels found in irrigation waters in these regions and the even lower levels that would likely make it to the edible portions of food crops via irrigation, these levels posed an extremely low risk to consumers of fresh produce.

Although none of the 297 irrigation water samples tested positive for the *E. coli* Shiga toxin genes (*stx1* and *stx2*), 13 samples (4.4 percent) did test positive for the presence of the intimin attachment and effacing virulence gene (*eae*), which represented 10 of the 99 triplicate samples (10.1 percent). Identification of the *eae* gene without the presence of *stx1* or *stx2* has also been noted previously by several other researchers. The presence of this virulence gene suggested the potential for these isolates to be pathogenic; however, as with the positive *Salmonella* samples, only one or two of the three replicates was positive, suggesting very low levels of the potentially pathogenic *E. coli* strain.

All 297 samples were also examined for the presence of heterotrophic plate count (HPC) bacteria, which allowed for a measurement of the general microbial quality of the irrigation waters. Heterotrophs are bacteria that require organic carbon for growth. Bacteria detected through HPC tests would generally include those that were part of the natural (typically non-pathogenic) microbiota of water. HPC values do not directly relate to health risk, but increases in HPC levels could sometimes be associated with contamination. Serial dilutions of the irrigation water samples were performed and 0.1 ml volumes of each dilution were inoculated onto duplicate R2A plates using the spread plate technique. After incubation at 30°C for five days, CFU on the plates were enumerated to determine the number of HPC bacteria per 100 ml of irrigation water. All samples had detectable HPC bacteria. The counts ranged from 4.0×10^3 to 3.2×10^7 CFU per 100 ml, with an arithmetic average of 1.56×10^6 CFU/100 ml and a geometric mean of 5.64×10^5 CFU/100 ml.

Virus analyses: The collected 3 L grab samples were concentrated for viruses by passage through stacked pre-filter membranes (pore size of 20 to 25 µm) and negatively charged HA filters (90 mm in diameter, pore size of 45 µm). Following elution from the HA filters (which resulted in the primary concentration of the samples from 3 L down to 10 ml). The samples also underwent a secondary concentration step in which the volume was further reduced to approximately 0.65 ml via a centrifugal ultrafiltration step. These secondary concentrates were frozen and stored at −80°C pending further evaluation. The sample concentrates were then purified and the nucleic acids extracted using MO BIO PowerViral™ Environmental RNA/DNA Isolation Kits. In a previous study by the principal investigator's research group, this kit was found to be more efficient for the extraction and purification of viral nucleic acids from environmental water concentrates than two other widely used commercial kits; it was also better at removing environmental inhibitors (Iker et al. 2013).

In the detection of viruses by quantitative PCR (qPCR), environmental inhibitory substances could reduce viral nucleic acid extraction efficiency and interfere with complementary DNA synthesis and/or polymerase activity, which could strongly affect the molecular detection and quantification of viruses in environmental samples. A known concentration of murine norovirus (MNV) was therefore added to each sample prior to the nucleic acid extraction step. The amount of MNV remaining in the sample following extraction and purification was assayed in separate qPCR reactions as a process control to determine the extraction efficiency for each sample. A known concentration of adenovirus 2 (AdV2) also was added to each sample following nucleic acid extraction and assayed in separate qPCR assays as a qPCR inhibition control to determine whether there were any substances that were inhibitory for the qPCR in any of the samples.

All 297 samples were then assayed via qPCR for the presence of viral indicators and pathogens. Assays for Aichivirus (AiV), pepper mild mottle virus (PMMV), and enteroviruses were performed with a LightCycler® 480 Real-Time PCR Instrument II (Roche Diagnostics, Mannheim, Germany) using previously established protocols and primer/probe sets. Aichivirus has been detected in high numbers in both raw and treated sewage in the United States, Japan, Venezuela, and Tunisia, and in shellfish in France. Although not a human pathogen, pepper mild mottle virus was the most abundant virus in fecally-contaminated waters worldwide; enteroviruses (a group of human enteric viruses) were also commonly found in contaminated waters. PMMV was detected in 76 of the 297 samples (25.6 percent), representing at least one of the three replicate samples in 60 of the 99 (61.0 percent) triplicate samples. Neither AiV nor the enteroviruses were detected in any of the irrigation water samples.

NGS analyses: The collected 2 L grab samples were concentrated for bacteria and protozoans by passage through stacked pre-filter membranes (pore size of 20 to 25 µm) and negatively charged HA filters (90 mm in diameter, pore size of 45 µm). The filters were placed in sterile petri dishes sealed with parafilm and stored at −80°C pending further evaluation.

For the recovery of microorganisms, the filters were each placed in separate sterile 50 ml conical tubes so that the top side of the filter was facing inwards. The bacteria and protozoans on the HA filters were then eluted from the filters in 10 ml of buffered peptone water with agitation for one minute on a vortexer using a 50 ml tube adapter. The filters were removed from the tubes and discarded and then the eluting solution was pelleted via centrifugation (10 minutes at approximately 3,500 × *g* rpm at room temperature) using a benchtop centrifuge. The supernatant was carefully removed and discarded and the pellet containing microorganisms was re-suspended in 400 µl of sterile physiological saline (0.85 percent NaCl at pH 7.0). The DNA from the bacteria and protozoans in 200 µl of this suspension was extracted using a bead-based homogenizer (i.e., bead-beater) and purified using a PowerLyzer® PowerSoil® DNA Isolation Kit. This kit was also efficient at the removal of environmental inhibitors. The extracts from the 297 samples were sent to a commercial laboratory to be sequenced using NGS technologies.

The analysis was accomplished using sequencing of genes such as the 16S rRNA gene, which was highly conserved among all bacteria, and the 18S rRNA gene, which was highly conserved among all eukaryotes (e.g., protozoans, fungi, algae). Small differences (e.g., three percent) in such a conserved gene could then be used to separate microorganisms at the species or near-species level. These defined differences were expressed as operational taxonomic units (OTUs). The DNA in each sample was amplified using PCR assays for both the 16S (to identify bacterial species) and 18S (to identify protozoan species) rRNA genes, and then sequencing reactions were performed using the PCR products using the Illumina HiSeq 2500 RR platform. Approximately 300,000 paired-end 2 x 250 bp reads were performed per sample. The Caporaso V4 515f – 926r primer sets used by the Earth Microbiome Project were used for the 16S analyses. For general eukaryotic 18S identification, the universal TAReukF and TAReukR primer set that amplified a ~380 bp region of the eukaryotic 18S rDNA was used. The following seven steps were performed for the resulting sequences generated: (i) Denoising – corrects errors in reads; (ii) Chimera Checking – formation of chimeric sequences occured when an aborted sequence extension was misidentified as a primer and was extended incorrectly in subsequent PCR cycles; (iii) FASTQ File Generation – text based formatted data files that store the nucleotide sequences generated by the sequencer and their corresponding quality scores encoded as ASCII characters; (iv) Quality Checking and FASTA Formatted Sequence/Quality File Generation – for use in subsequent analyses; (v) Sequence Clustering – placed sequences into clusters using an OTU selection program; (vi)

Taxonomic Identification – phylogenetic trees were constructed and sequences were compared to several databases for classification; and (vii) Diversity Analysis.

Of the 297 individual samples for bacterial analyses (16S rRNA gene), 16 did not amplify using the primer sets. This result was likely due to PCR inhibitors that were naturally found in the irrigation water samples. Nevertheless, for each sampling location/time, at least one of the triplicate samples was amplified in all but two instances. In other words, of the 99 samples collected in triplicate over the course of the project, sequencing information was available for 97. For the eukaryotic analyses (18S rRNA gene), successful PCR amplification was observed in far fewer samples. This result was likely primarily due to fewer eukaryotes (e.g., protozoans, fungi, algae) being present in the samples rather than simply inhibition of the PCR (though all of the samples exhibiting inhibition in the bacterial analyses also had limited or no amplification in the 18S analyses). Amplification was observed in only 134 of the 297 individual samples for 18S; sequencing information was available for a total of 62 of the 99 triplicate samples.

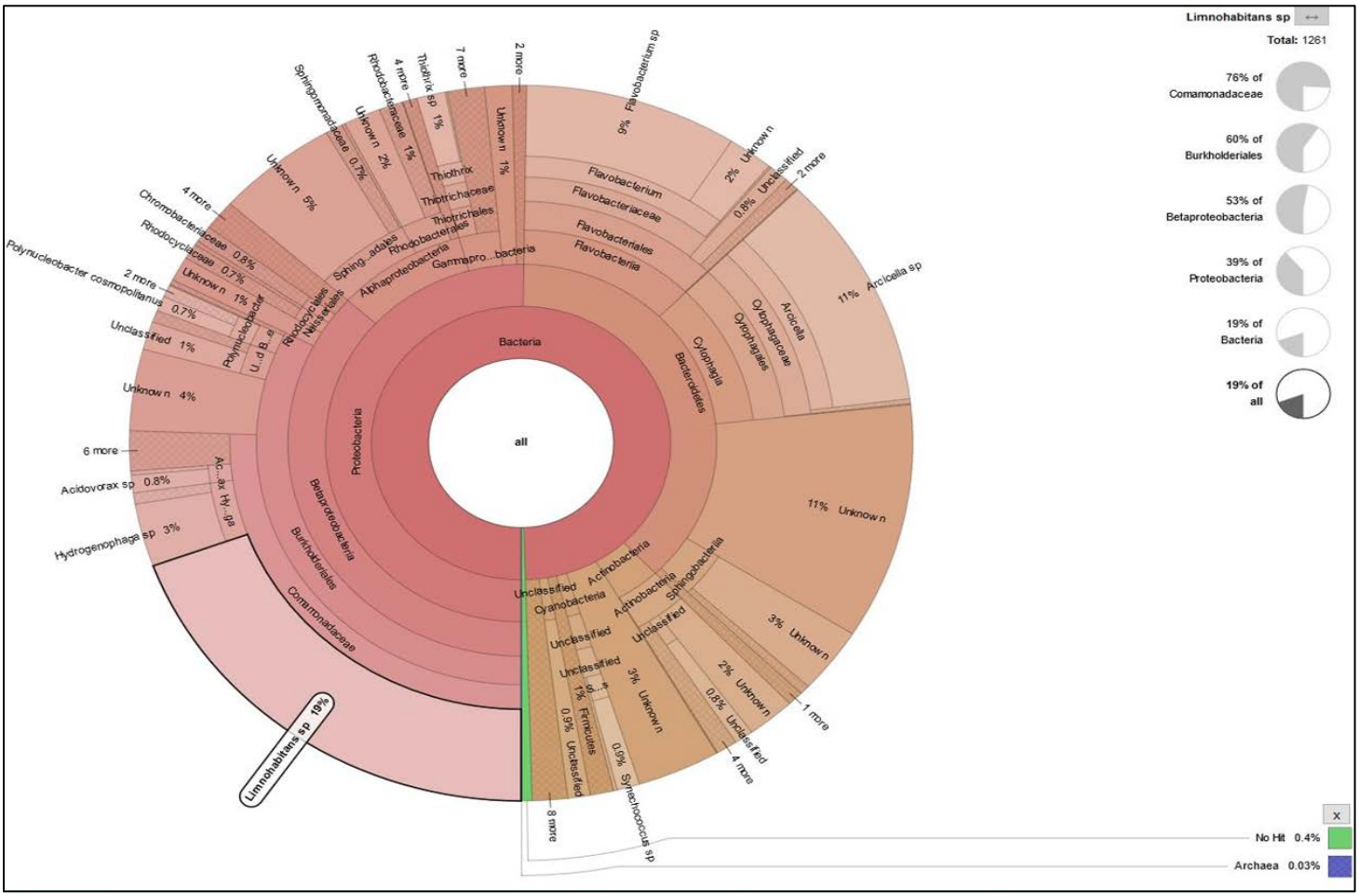

Figure 1. Example Krona chart that shows the bacterial diversity in a single sample of irrigation water. The results for *Limnohabitans* species are highlighted in the figure (bottom left) and to the right.

For each amplified sample, a Krona diversity chart was generated. An example chart is shown in Figure 1 (above). Based on this information, the most abundant organisms per sample were determined. Preliminary

analyses identified 21 basic genetic "profiles" for the irrigation waters included in the study. These were based on the top five most abundant organisms present for each set of triplicate samples, and did not consider the entire makeup and diversity of the samples. Nevertheless, some interesting trends were observed. For instance, more diversity was found in Arizona's Region Two, which historically had higher levels of contamination than Region One. Profile 5 was found in 33.3 percent of the triplicate samples from Region Two; Profile 2 was found in 20.0 percent of the samples. Seven other profiles were each found in approximately 6.7 percent of samples. For Region One, nine profiles were also observed; however, they exhibited less overall diversity (found in 38.0%, 25.4%, 18.3%, 8.5%, 2.8%, 2.8%, 1.4%, 1.4%, and 1.4% of samples, respectively). For this region with historically lower contamination levels, a few profiles were found a majority of the time (Table 1 below). This result suggested that with more contamination inputs, greater microbial diversity could be observed. In addition, the most commonly found profiles differed greatly between the two regions in Arizona that were included in the study. For instance, Profile 1 was found in 38 percent of samples in Region One, yet was only found in 6.7 percent of samples in Region Two. Profile 5, which was found in 33.3 percent of samples in Region Two, was only found in 1.4 percent of samples in Region One (Table 1).

Table 1. Summary of the microbial diversity found in primary irrigation canals and return flow canals from two regions in Arizona. The bacterial microbiome "profiles" are based upon the top five most abundant organisms found across the triplicate samples.

Bacterial Microbiome "Profile"	Region 1 Canals			Region 1 Return Flow Canals			Region 2 Canals		
	Winter	Summer	Total	Winter	Summer	Total	Winter	Summer	Total
1	75.0%	-	38.0%	-	14.3%	9.1%	14.3%	-	6.7%
2	2.8%	48.6%	25.4%	-	14.3%	9.1%	28.6%	12.5%	20.0%
3	11.1%	25.7%	18.3%	-	-	-	-	-	-
4	2.8%	2.9%	2.8%	-	-	-	14.3%	-	6.7%
5	2.8%	-	1.4%	-	-	-	14.3%	50.0%	33.3%
6	-	17.1%	8.5%	-	-	-	-	-	-
7	-	-	-	25.0%	-	9.1%	-	-	-
8	5.6%	-	2.8%	-	-	-	-	-	-
9	-	-	-	-	14.3%	9.1%	-	-	-
10	-	-	-	-	14.3%	9.1%	-	-	-
11	-	-	-	-	-	-	-	12.5%	6.7%
12	-	2.9%	1.4%	-	-	-	-	-	-
13	-	2.9%	1.4%	-	-	-	-	-	-
14	-	-	-	25.0%	-	9.1%	-	-	-
15	-	-	-	25.0%	28.6%	27.3%	-	-	-
16	-	-	-	-	-	-	14.3%	-	6.7%
17	-	-	-	-	-	-	14.3%	-	6.7%
18	-	-	-	-	-	-	-	12.5%	6.7%
19	-	-	-	-	-	-	-	12.5%	6.7%
20	-	-	-	-	14.3%	9.1%	-	-	-
21	-	-	-	25.0%	-	9.1%	-	-	-

Large seasonal differences were also observed in both regions (Table 1). For instance, 75.0 percent of samples collected during the winter in Region One were from Profile 1; this same profile was not observed in any samples from this region collected during the summer. For Region One, 48.6 percent of samples collected during the summer were from Profile 2, but only 2.8 percent of samples collected during the winter were from Profile 2. For Region Two, the most abundant profile found in the winter was Profile 2 (28.6 percent); the most abundant profile found in the summer was Profile 5 (50.0 percent).

In addition to these regional differences in microbial populations, large differences were observed between primary irrigation canals and return flow (drainage) canals in Region 1 (Table 1). With return flows, the excess water used to irrigate one field was collected (e.g., in drainage canals in this Region) and the water was subsequently used to irrigate fields downstream. Such return flows were known to have lower microbial and chemical water quality as they picked up many contaminants on their way through the fields. As with the areas from Region Two with historically higher contamination levels than Region One, the water samples collected from these return flow canals also had greater microbial diversity than the waters collected from the primary irrigation canals. In addition, the microbial profiles from the return flow canals exhibited very little overlap in microbial profiles with the waters collected from primary irrigation canals in either region.

Nearly all fresh produce commodities grown in Arizona were considered specialty crops. All of these crops were irrigated via open conveyance canal systems using surface waters. In this project, the team determined the presence of foodborne pathogens and indicators of fecal contamination and compared these to the entire microbial populations (the microbiome) found in the irrigation water samples. These results provided region and/or season-specific identification of species or microbial population shifts which may be used to identify changes in the microbial quality of specific irrigation water systems. The scientific data gained from this project will be used towards meeting the United States Food and Drug Administration's water quality standards. This could allow producers of specialty crops to make risk-based assessments of water quality and help to determine when it is safe to irrigate fields, which will lead to improved produce safety and increased consumer confidence in these specialty crops.

This project did not enhance the competitiveness of non-specialty crops.

The project partners were the Center for Produce Safety and the University of Arizona. The Center for Produce Safety managed the project and the University of Arizona performed the research studies. The principal investigator oversaw all aspects of the sample collection and the laboratory research and analyses, and was responsible for the preparation of all reports and presentations. The principal investigator also supervised the work of the laboratory personnel. The principal investigator will be involved in the preparation of any manuscripts for submission to peer-reviewed publications. The co-principal investigator was responsible for overseeing the molecular laboratory work such as the nucleic acid extractions, PCR, and sequencing analyses. The co-principal investigator assisted the principal investigator with the analysis of the research data and with the preparation of reports, and will assist in the preparation of manuscripts for submission to peer-reviewed scientific publications.

Goals and Outcomes Achieved

Activities associated to identify groups of organisms or specific species whose presence correlated well with the occurrence of foodborne pathogens in irrigation waters included (i) examination of collected irrigation water samples to determine the levels of indicator and pathogenic species by existing cultural and molecular

methods, (ii) measurement of physicochemical water quality parameters and canal characteristics of the irrigation water samples (iii) examination of the irrigation water samples to determine the levels of viruses known to be found in high concentrations in fecally-contaminated waters, (iv) determination of the presence and relative abundance of the entire prokaryotic and eukaryotic microbial communities found in the irrigation water samples, and (v) NGS microbiome analyses of the irrigation water samples.

Long-term outcome measures included sharing of results at both professional and industry meetings (see Additional Information) and measuring the attendance at meetings. Interim project results were presented at the annual Center for Produce Safety Symposium in 2016 (325 attendees) and 2017 (325 attendees). Presentations of some results were also made in 2017 at the annual meeting of the International Association for Food Protection (75 attendees) and at the Arizona Water Conference (35 attendees). Presentations in 2018 included the Center for Produce Safety Symposium (June) (300 attendees). The Yuma Safe Produce Council (YSPC) meeting was not held in 2018. Instead, 9 members of the YSPC council, and 11 University of Arizona faculty members met with the project principal investigator to learn about the research being conducted. A presentation summarizing project results will be presented to the entire YSPC in early 2019. The original project proposal also listed the University of Arizona Food Safety Conference as a venue for a presentation but this event did not take place within the duration of the project. Other conferences and meetings were not attended in past years due to a lack of travel funds and a limited amount of results to present until late in the project term. In addition, preparation began on a research paper for a peer-reviewed scientific publication.

Although the NGS microbiome analyses were ongoing, the preliminary analysis of the sequencing data provided information regarding both significant regional and seasonal differences between irrigation canals in Arizona. In addition, systems/canals with known higher levels of contamination (e.g., those with historically higher levels of contamination/possible contamination inputs and return flow canals which included run-off from agricultural fields) exhibited more microbial diversity than those with historically lower levels of contamination/contamination inputs. In addition, the bacterial population profiles of the most abundant organisms present varied greatly between such areas.

It was therefore apparent that the “normal” composition or “baseline” levels of microorganisms/ populations needed to be determined for each region prior to undertaking any such NGS evaluation of the effects of various contamination inputs. Nevertheless, once such baseline evaluations have been conducted, NGS could provide valuable information on any changes such inputs may have had on the microbial water quality. For instance, the baseline predominant organisms for a region could be determined and rapid tests developed for their identification (e.g., molecular assays such as PCR). These could be used for the routine monitoring of the irrigation water in the region. A change or shift in the populations could stimulate further testing such as testing for specific pathogens or other indicator organisms aside from *E. coli* (e.g., specific indicators of fecal contamination) or indicate to the farmer that mitigation steps might be necessary (e.g., waiting to irrigate, allowing for die-off of pathogens between the final irrigation event and produce harvest, treatment of the water source).

This work should result in an approach that will provide region and/or season-specific identification of species or microbial population shifts which may be used to identify changes in the microbial quality of irrigation waters. This could allow members of the fresh produce industry to make risk-based assessments of water quality and help to determine when it is safe to irrigate fields.

The original proposal set out to identify novel indicator organisms that could be better correlated with the presence of foodborne pathogens rather than fecal contamination of irrigation waters and existing indicators such as generic *E. coli*. A total of 99 irrigation water samples were collected in triplicate (three replicate samples for a total of 297 samples) from two different fresh produce growing regions in Arizona over a two-year period. The levels of indicator species (i.e., generic *E. coli*) and pathogenic species (i.e., Shiga toxin–producing *E. coli* and *Salmonella*) species were determined in all 297 samples by existing cultural and molecular methods (Objective 1). The levels of viruses known to be found in high concentrations in fecally-contaminated waters (i.e., pepper mild mottle virus, Aichiviruses, and enteroviruses) were determined in all 297 samples (Objective 2). The composition (presence and relative abundance) of the entire prokaryotic (bacterial) and eukaryotic (e.g., protozoan, fungal, algal) microbial communities was determined for all 297 samples (Objective 3). And finally, preliminary analyses to identify groups of organisms or specific species whose presence correlated well with the occurrence of foodborne pathogens in irrigation waters (Objective 4) were completed and were included in this report, however, the project team planned to conduct more detailed analysis after the duration of the grant.

The baseline data gathered to date included analysis of 297 irrigation water samples for the following: generic *E. coli* (indicator species) and Shiga toxin–producing *E. coli* and *Salmonella* (pathogenic species); pepper mild mottle virus, Aichiviruses, and enteroviruses (found in high concentrations in fecally-contaminated waters); composition of entire prokaryotic and eukaryotic microbial communities. Physicochemical water quality parameters and canal characteristics of the irrigation water samples were also determined. In addition, NGS microbiome analyses were conducted on the 297 irrigation water samples for both the 16S rRNA gene (bacteria) and the 18S rRNA gene (eukaryotic organisms such as protozoans, fungi, and algae). The preliminary analysis of the sequencing data provided information regarding both significant regional and seasonal differences between irrigation canals in Arizona. In addition, systems/canals with known higher levels of contamination (e.g., those with historically higher levels of contamination/possible contamination inputs and return flow canals which included run-off from agricultural fields) exhibit more microbial diversity than those with historically lower levels of contamination/contamination inputs. In addition, the bacterial population profiles of the most abundant organisms present varied greatly between such areas.

The irrigation water samples were examined for a number of microbial, chemical, and physical water quality parameters as well as the canal characteristics (e.g., main canal vs. lateral canal vs. drainage canal, cement-lined vs. unlined, urban vs. rural): the water temperature, pH, turbidity, electro-conductivity, salinity, and total dissolved solids; the numbers of total coliforms and *E. coli* (both generic and those with Shiga toxin–producing *E. coli* [STEC] virulence genes); the numbers of HPC bacteria; the presence of *Salmonella* species through enrichment/selection; and the levels of viral pathogens (enteroviruses and Aichiviruses) and viral fecal indicator species (pepper mild mottle virus). NGS microbiome analyses were conducted on the 297 irrigation water samples for both the 16S rRNA gene (bacteria) and the 18S rRNA gene (eukaryotic organisms such as protozoans, fungi, and algae). This likely constituted the largest collection of metagenomics information ever collected for irrigation waters. These sequences could be analyzed in a number of different ways in the future to provide information even beyond the scope of the current project. All of the water quality parameters and information on the presence/quantities of microbial indicators/pathogens will be used as meta-data to compare with the microbial populations (both presence and relative abundances) found in each of the samples via NGS. It was the hope of the investigators that specific species (i.e., novel indicator organisms) or shifts in the microbial populations (such as those observed by the

team) could be correlated with changes in the microbial quality of irrigation waters and provide meaningful information regarding the potential safety of the water for use in irrigation of food crops.

Beneficiaries

All growers of specialty crops in Arizona could potentially benefit from the results of this work, and many major California growers also have operations in Arizona. This project should result in an approach that will provide region and/or season-specific identification of species or microbial population shifts which may be used to identify changes in the microbial quality of specific irrigation water systems. The project results will have a broad impact on the produce industry in California by enabling stakeholders to make risk-based assessments of water quality and help to determine when it is safe to irrigate fields.

The results from this project should benefit at least 500 large and small-scale growers and producers of specialty crops in Arizona.

The principal investigator from the University of Arizona presented final research results in June 2018 at the 9th annual Center for Produce Safety Research Symposium in Charlotte, North Carolina, to 300 symposium attendees. Interim results were presented previously in an oral presentation at the 2017 Center for Produce Safety Research Symposium in Denver, Colorado (325 attendees), and in a poster session at the 2016 Center for Produce Safety Research Symposium in Seattle, Washington (315 attendees). The symposium participants included California regional and national growers and shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provided expert panels to discuss the research results after presentation by the researcher, which helped participants evaluate how the results could be used in their respective businesses.

Project results were disseminated at industry meetings, and streamed through social media sources. Results were also made available online as follows:

1. Final report to the Center for Produce Safety Research was posted on the Center for Produce Safety Research website: https://www.centerforproducesafety.org/grant_opportunities_awards.php
2. Center for Produce Safety Research worked with the scientists to publish results in scientific journals. Publication dates occur after the project is completed. Abstracts and awards can be found on the Center for Produce Safety Research website.
3. The Board of Directors and members of the Technical Committee of Center for Produce Safety Research distribute a series of information briefs throughout the year on the website and through presentations, meetings and webinars. An example of this would be the “2017 Center for Produce Safety Research Symposium – Key Learnings” on the Center for Produce Safety Research website, available in both English and Spanish, at the following link: https://www.centerforproducesafety.org/key_learnings.php

The following websites provide additional resources on the final reports and symposium proceedings:

Center for Produce Safety: https://www.centerforproducesafety.org/resources.php
Produce Marketing Association: https://pma.com/topics/food-safety/center-for-produce-safety
Western Growers Association: https://www.wga.com/

Lessons Learned

One lesson learned was the need for attention to budgeting and approval for NGS. The costs for the NGS were underestimated in the original budget. Also, university approval of the purchase order for the sequencing assays took longer than expected. These amendments and approvals delayed the start of the NGS assays for the irrigation water samples. In addition to these delays, the original PCR amplification of the irrigation water samples required some troubleshooting, which further delayed the onset of the NGS steps.

One unexpected outcome was that the processing of the 297 samples for all of the various analyses took longer than anticipated.

The lack of amplification in numerous samples during the initial PCR step for 16S and 18S rRNA gene detection required the team to troubleshoot, which resulted in further delaying the final sequencing work. The sequences that were expected to be completed by late January 2018 were instead not generated until the last week of February 2018. Because of this delay, more detailed sequencing analyses have yet to be performed. These analyses required the use of computers with a large amount of processing power (e.g., a “super computer”) and additional time (days to weeks depending on the depth of the analyses). However, all of the other goals of the project were met.

Additional Information

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Presentations:

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Bright, KR. 2017. Assessment of the microbial quality of irrigation waters in the Southwest U.S. Annual Meeting of International Association for Food Protection, Tampa, FL, July 9–12.

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CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 60	**Project Title:** Control of cross-contamination during field-pack and retail handling of cantaloupe	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB15060	**Date Submitted:** December 2018
Recipient Contact: Bonnie Fernandez-Fenaroli	**Telephone:** (530) 554-9761	**Email:** bonnie@centerforproducesafety.org

Project Summary

Recently, the melon industry has faced high-profile outbreaks of foodborne illness in the United States (U.S.). In 2011, a *Listeria monocytogenes* outbreak associated with cantaloupes (from Colorado) resulted in 147 illnesses and 33 deaths in 28 states (McCollum et al., 2013), and in 2012, a *Salmonella* outbreak, also associated with cantaloupe (from Indiana) resulted in 261 illnesses and 3 deaths in 24 states (FDA, 2013). While neither of these outbreaks was associated with cantaloupes from California, the California cantaloupe industry suffered significant economic losses (Russell, 2014). In an effort to rebuild consumer confidence in the safety of cantaloupes, the industry adopted a mandatory food safety plan for all cantaloupe producers in California, involving a series of food safety checkpoints and completion of a California Department of Food and Agriculture audit. Additionally, the California Cantaloupe Advisory Board and the California Melon Research Board partnered with the Center for Produce Safety (CPS) to fund research projects related to melon food safety. Previous research focused on microbial hazards and risks during growing or holding of melons, but little research has focused on understanding those risks during field-pack and retail handling of melons. Data was lacking on the identification of "high risk" cross-contamination points and mitigation strategies for melons packed in the field. The 2011 and 2012 cantaloupe outbreaks linked to packinghouse sanitation are contrasted by the recent speculation by certain produce commodity groups on the increased risk(s) associated with field-packed produce. This project focused on identifying "high risk" cross-contamination points during field-pack and retail handling of melons, and bridging the gaps on which to base melon-specific best practice guidance to reduce the likelihood of cross-contamination events from harvest through to consumers.

This project is important and timely because netted melons (e.g., cantaloupe) are widely seen as a high-risk produce commodity, and U.S.-grown cantaloupe have been implicated in recent foodborne illness outbreaks. Foodborne pathogen contamination of melons can occur at various points along the distribution chain (e.g., production, packing, storage) (Parnell et al., 2005; Suslow, 2010), and data on control of cross-contamination of foodborne pathogens during field-pack and retail handling of melons is relatively scarce. Previous research has shown cross-contamination to be a factor in microbial contamination of produce. Moreover, cross-contamination can occur during harvesting and packing of produce due to the use of contaminated equipment and or improper handling by workers (Brar et al., 2013; Sreedharan et al., 2014). Similar studies on other commodities and environments have found movement of pathogens from one surface to another is dependent on the type of bacteria (MacKintosh and Hoffman, 1984), type of surface (Chen et al., 2001), moisture level (Gill and Jones, 2002), and inoculation dose (Montville and Schaffner, 2003). Ultimately, the data generated in this project identified variables that are associated with an increased occurrence of cross-contamination points or events during field-pack and retail handling of melons. Figure 1.0 (see Attachment 1) illustrates the various cantaloupe contact surfaces throughout the supply chain. Once variables were identified that contribute to "high risk" cross-contamination points or events during field-pack and retail handling of melons, appropriate mitigation and intervention strategies were developed to reduce the likelihood of those cross-contamination risks.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Objective 1 (Quantify the transfer of *Salmonella* and *L. monocytogenes* onto melons in field-packing operations from each potential cross-contamination surface). This objective focused on identifying the transfer coefficients using a dry inoculum, except when water/sanitizers might be present, to determine the contamination risk of certain practices in field-pack melon operations. First, experiments were performed to identify a dry inoculation procedure that could uniformly and consistently be used to stimulate *Salmonella* or *L. monocytogenes* contamination in a dry environment. Three methods of drying were evaluated and three carrier mediums were tested. The final dry inoculation procedure that was selected consisted of the following: liquid *Salmonella* or *L. monocytogenes* inoculum (17.5 mL; ~8–9 log CFU/mL) was mixed with 100 g of sterilized sand and dried in a sterile weigh boat (no filter paper) for a minimum of 24 hours in a desiccator with vacuum. The average amount of *Salmonella* and *L. monocytogenes* recovered after the dry inoculation procedure was ~7 and 6 log CFU/g, respectively. Next, to simulate contamination events, surface coupons or melon pieces were shaken and rubbed in the 100 g of dry pathogen-sand mixture in sterile bags (up to 1 minute); subsequent experiments to simulate likelihood of cross contamination were performed by applying different amounts of pressure and contact from the contaminated surface coupon (5–6 log CFU/coupon) to melon or from contaminated melon (5–6 log CFU/piece) to the surface coupon. The next phase was to evaluate the pathogen transfer from contaminated melons to contact surfaces and vice versa (from contaminated surface to melon) upon single and subsequent touches. The contact surfaces tested included cotton (gloves, rags), rubber (gloves), nitrile (gloves), stainless steel (pack tables, knives), polyethylene (pack tables), and plastic bristles (brushes).

The transfer of *Salmonella* and *L. monocytogenes* from contaminated cantaloupe to surfaces or from contaminated surfaces to cantaloupe was low when using a dry inoculum. Since transfer was low, it is imperative to have a good sanitation program to prevent pathogen harborage sites or pathogen biofilm formation (which may aid in transfer). Best practices should include cleaning and sanitizing the contact surfaces on schedule (e.g., daily). The transfer of both pathogens from contaminated cantaloupe to surfaces or from contaminated surfaces to cantaloupe was not significantly different for all tested surfaces when using a wet inoculum, except for the cotton contact surface. It was hypothesized that the wet inoculum soaked into the cotton material and this increased the contamination potential or transfer to cantaloupe and/or surfaces.

In general, less pathogen transfer can be expected with shorter contact times and with more pressure or friction. For example, there was less transfer of *Salmonella* from contaminated cantaloupe to glove surfaces or from contaminated gloves to cantaloupe with 5 and 10 seconds contact than with 20 seconds contact (Figure 1.1); similar results were obtained for transfer of *L. monocytogenes*. Very low transfer coefficients were obtained from tests with polyethylene and plastic bristles. For example, using mild pressure and a medium contact time (10 seconds), which are conditions often observed for a typical field-pack melon harvest operation, the transfer coefficients from inoculated melon to polyethylene were 0.07±0.02 (or ~7 percent), and those from inoculated polyethylene to melon were 0.05±0.03 (or ~5 percent). Lower transfer coefficients (<5 percent) were observed in tests with plastic bristles and cantaloupe. The plastic bristle brushes were very difficult to inoculate compared with cotton, rubber, or smooth surfaces (e.g., stainless steel and polyethylene).

In general, there was less transfer of *Salmonella* and *L. monocytogenes* from contaminated cantaloupe to some surfaces or from contaminated surfaces to cantaloupe with more (vigorous) pressure than with mild and no

pressure. To investigate further, the three pressures were studied to elucidate pathogen transfer with the three types of glove contact surfaces after a contact time of 20 seconds. The team observed that more pressure actually resulted in greater *Salmonella* transfer for rubber gloves compared with cotton and nitrile gloves (Figure 1.2); similar results were obtained for transfer of *L. monocytogenes*. Rubber gloves had the most transfer of *Salmonella* and *L. monocytogenes*, regardless of contact time or pressure, while nitrile gloves had the least transfer; the rubber gloves commonly used on harvesters and in experiments had ridged grooves. Interestingly, when pressure was standardized, cotton gloves behaved similarly to nitrile gloves.

Additionally, the Principal Investigator (PI) and research technician visited field-packing operations in California and Arizona to observe melon harvest and perform environmental swabbing of contact surfaces to assess the microbial quality of each surface throughout the operational run. The focus was to swab contact surfaces at different operations and of different crews. Figure 1.3 shows the different glove types and the swabbing of surfaces. Three different melon operations were visited in June 2016: AZ1 (Yuma, Arizona; specialty melons); CA1 (Blythe, California; cantaloupe); and CA2 (Holtville, California; cantaloupe). At each location, the team visited with management leadership/staff and discussed surfaces that melons may come in contact with (also which contact surfaces were single-use and which were sanitized, and the sanitation process). For AZ1, a total of five harvesters were sampled at two timeframes: morning (7 a.m. to 10 a.m.) and afternoon (11 a.m. to 2 p.m.). For CA1 and CA2, six harvesters were sampled at each site at the same two timeframes. A total of 284 swabs were collected (80, 102, and 102 from AZ1, CA1, and CA2, respectively) during the trips. Specifically, AZ1 contact surfaces consisted of cotton gloves for both pickers and packers, cotton rags, plastic bristle brushes, stainless steel pack tables and knives; CA1 contact surfaces consisted of nitrile gloves for both pickers and packers, plastic bristle brushes, stainless steel and cardboard-covered pack tables, and stainless steel knives; and CA2 contact surfaces consisted of rubber gloves for both pickers and packers, plastic bristle brushes, stainless steel and vinyl-covered pack tables, and stainless steel knives.

No significant difference in microbial load was observed for aerobic plate count, coliforms, or generic *E. coli* between swabs collected at the two timeframes (morning and afternoon; $P \leq 0.05$). This result was surprising to the research team but not to the melon industry. The conditions during field-pack are quite dry (average temperature was >100°F on each day that samples were collected) and equipment and melons stay relatively "clean" throughout the day. Dirt or grime accumulation was observed only when fields were a bit wet from the dew; this occurrence was rare and thus did not significantly affect the overall data.

Figure 1.4 shows a comparison of microbial loads (aerobic plate count, coliforms, and generic *E. coli*) on field-pack contact surfaces collected between 7 a.m. and 10 a.m. (morning timeframe) is shown. No significant differences in microbial loads were observed among the type of gloves worn by pickers or packers (nitrile, rubber, or cotton); however, there was a general trend that lower microbial loads were found on packers' than on pickers' gloves. This result may be due to pickers' hands being closer to the soil as they are cutting melons from the vine, whereas packers transfer melons into single-use boxes. Also, no significant difference in microbial loads was observed among pack table surfaces (stainless steel, vinyl, and cardboard); however, there was a clear trend that lower microbial loads were found on the stainless steel pack tables and higher loads on the vinyl-covered pack tables. Interestingly, when this finding was discussed with field harvest staff, the research team was informed that the vinyl-covered tables are not typically used for field-packing netted melons, such as cantaloupe, but are used for smoot melons, such as honeydew (and apparently a few harvesters had been borrowed from the honeydew portion of their operation). Overall, the field sampling performed in June 2016 was very informative. A small number of swabs were collected after

sanitation procedures had been performed by the three operations (only swabbing of harvester pack tables was allowed, n=69; no swabbing was performed on cardboard-covered pack tables as the cardboard is thrown out after use). Coliforms and generic *E. coli* were undetectable in all swab samples post-sanitation.

Objective 2 (Compare the effect of different sanitizers on *Salmonella* and *L. monocytogenes* survival on potential cross-contamination surfaces). First, a series of survival studies for *Salmonella* and *L. monocytogenes* was performed in the laboratory to determine the rates at which the respective pathogen survived on each contact surface over the course of a day. A day (8 hours) was the maximum time point, as most CA/AZ field-packing melon operations clean and sanitize at the end of each operational run (Russell et al., 2014). Cleaning consisted of removing all debris and dirt from contact surface materials by water and a detergent. After cleaning, a sanitizer (i.e., chlorine or peroxyacetic acid) is sprayed on the contact surface to decontaminate it from potential pathogens. Therefore, contact surfaces on which *Salmonella* and *L. monocytogenes* were observed to survive throughout the day were subjected to efficacy tests with the sanitizers used in field-packing operations. The goal of this objective was to determine (i) which contact surfaces have the greatest pathogen survival throughout the day (time points 0, 2, 4, 6 and 8 hours) when contaminated, and (ii) the most effective sanitizer to reduce the likelihood of cross-contamination (or transfer of pathogen between contact surface and melon) for the targeted contact surface.

In general, while both pathogen populations declined on contact surfaces over the 8 hours, pathogen survival was greater when contact surfaces were fouled versus clean. (A surface was rubbed with a cantaloupe leaf for 20 seconds to simulate a “fouled” surface.) Also, in general, pathogen survival was greater when contact surfaces were inoculated with a wet versus dry inoculum. Survival of the pathogens on fouled and clean (new) contact surfaces when using wet and dry inoculums is shown for *L. monocytogenes* (Figure 2.1–2.4) and *Salmonella* (Figure 2.5–2.8) on the different gloves and stainless steel. For example, pathogen survival was significantly higher over 8 hours ($P \leq 0.05$) on stainless steel surfaces inoculated using a wet inoculum compared with a dry inoculum (Figure 2.4 and 2.8, respectively). This result is of particular interest as several studies have been performed using wet inoculums. A dry inoculum was used to simulate real-world conditions since West Coast cantaloupe production is typically dry (i.e., minimal water is used during cantaloupe harvest). When using a wet inoculum, *L. monocytogenes* survival was significantly greater at 8 hours ($P \leq 0.05$) on fouled rubber and nitrile gloves compared with clean rubber and nitrile gloves (Figure 2.2 and 2.3, respectively); however, when using a dry inoculum, this trend was only observed for the rubber gloves. No significant difference in *L. monocytogenes* survival was observed on fouled or clean cotton gloves at 8 hours, regardless of inoculum type (Figure 2.1). Interestingly, *Salmonella* survival was significantly greater at 8 hours ($P \leq 0.05$) on fouled cotton gloves than on clean cotton gloves (Figure 2.5) but only when using a wet inoculum. This result was likely due to the wet inoculum soaking into the cotton material (and influencing survival). No significant difference in *Salmonella* survival was observed over 8 hours between fouled and clean rubber and nitrile gloves, regardless of inoculum type (Figure 2.6, 2.7). Typically during harvest, gloves are changed daily (as the team observed and through personal communication with cantaloupe stakeholders). For example, nitrile gloves are single-use and changed during any breaks or stoppage of work; cotton and rubber gloves are collected daily and laundered. The project data collected provides evidence that rubber gloves are more likely to be associated with contamination events as they become fouled over the course of 8 hours. Therefore, rubber gloves should be used with caution or used sparingly (as a last choice in protective glove attire). Data showed that rubber gloves were associated with the highest transfer potential of *L.*

monocytogenes and *Salmonella* from contaminated cantaloupe to surfaces or from a contaminated surface to cantaloupe.

Similar trends were observed for the plastic-type contact surfaces. Populations of both pathogens declined on plastic bristle brushes and polyethylene over the 8 hours (with both populations significantly declining between 0 and 8 hours). When a wet inoculum was used, *Salmonella* and *L. monocytogenes* survival was significantly greater at 8 hours ($P \leq 0.05$) on fouled plastic bristle brushes and polyethylene surfaces compared with clean plastic bristle brushes and polyethylene surfaces. When a dry inoculum was used, no significant difference in *Salmonella* and *L. monocytogenes* survival was observed between fouled and clean plastic bristle brushes and polyethylene at 8 hours. This result was similar to that for nitrile gloves, and may reflect the similar smooth nature of the contact surfaces.

Sanitation of stainless steel was targeted for further study. Stainless steel is a common contact surface in cantaloupe harvest, handling, and packing operations, and includes pack tables and knives. Experiments were performed to investigate sanitation of stainless steel with no treatment, water, chlorine (150 ppm), and peroxyacetic acid (PAA) (80 ppm). Two contact times were selected: 30 minutes and 15 hours (based on direct input from stakeholders). Sanitation of cantaloupe harvesters generally occurs at the end of operation (overnight, 15 hours) and directly before operations begin (30 minute contact). *Salmonella* and *L. monocytogenes* populations inoculated on clean stainless steel showed larger reductions after treatment compared with populations on fouled stainless steel. Thus, fouled surfaces were more difficult to sanitize, which highlights the importance of cleaning surfaces prior to sanitizing. This finding was most evident when analyzing the data from the sanitizer chlorine. After a 30 minute chlorine treatment, survival of *Salmonella* and *L. monocytogenes* populations was greater ($P \leq 0.05$) on fouled than on clean stainless steel (Figure 2.9 and 2.12, respectively). For fouled stainless steel contaminated with *Salmonella*, a 30 minute treatment with PAA decreased *Salmonella* populations more than treatment with chlorine (Figure 2.10). However, the same trend was not observed for *L. monocytogenes*, as populations remained high on fouled stainless steel surfaces regardless of 30 minute sanitizer treatment (chlorine or PAA) (Figure 2.13). Interestingly, chlorine and PAA were effective against *Salmonella* and *L. monocytogenes* with a 15 hour contact time (Figure 2.11 and 2.14, respectively). Therefore, when stainless steel surfaces are clean, both chlorine and PAA are effective against *Salmonella* and *L. monocytogenes* with a 30 minute contact time; however, if stainless steel surfaces are fouled, a shorter contact time (e.g., 30 minutes) is not recommended, especially when using a chlorine treatment.

Objective 3 (Assess melon handling practices at retail through case study methodologies including interviews and observation to identify potential risk factor points). This objective focused on using different tools—environmental monitoring at retail and surveys of food safety managers at major retailers—to utilize both quantitative and qualitative data to provide a complete picture of cantaloupe handling in the retail sector, from distribution to display. This objective included investigation into both whole cantaloupe and fresh-cut cantaloupe that was handled within the retail setting (not processed by a supplier).

Meetings were held with industry representatives from two retail partners to facilitate the identification of contact surfaces. A tour of a retail location was provided by a Retail Food Safety Specialist to assist in identification and confirmation of surfaces— for ability to sample and for surfaces that cantaloupe actually contacted. Surface usage rates and sanitation procedures were cataloged for the five associated retail locations. With industry assistance from the retail partners, seven and six surfaces were ultimately selected as

final sampling sites for retail partner 1 and 2, respectively. Several contact surfaces were excluded, including cardboard shipping containers, gloves, and packaging materials that were used only once prior to disposal (or recycling). For retail partner 1, the seven surfaces that were to be sampled included (1) wash sinks, (2) plastic lugs used to transport whole melons, (3) drying racks used to dry melons after washing, (4) knives used to cut melons, (5) cutting boards, (6) foam padding used in displays of whole melons, and (7) melon-holding display structures (i.e., the front and side material used to contain melons in the display bins). For retail partner 2, the six surfaces that were to be sampled included (1) plastic carts used to cart melons to the retail floor, (2) reusable plastic containers (RPCs) used for display, (3) wood holding display structures, (4) mesh used in displays, (5) styrofoam fruit cups used in displays, and (6) plasticor sheeting used in displays. The retail partners provided access to five stores (retail partner 1 in a southern state between mid-October and late-November 2016, and retail partner 2 in a northern state in fall 2017). At each location, a 10 cm by 10 cm area was sampled for each contact surface. For retail partner 1 the sampling occurred over four time points: before store opening (~5 a.m.), before mid-day cleaning (~12 p.m.), after mid-day cleaning (~2 p.m.), and before closing (~10 p.m.); and for retail partner 2 the sampling occurred over five time points: 6 a.m.–7 a.m., 10 a.m.–11 a.m., 2 p.m.–3 p.m., 6 p.m.–7 p.m., and 10 p.m.–11 p.m. Contact surfaces were swabbed using 3M swab sticks with Dey-Engley neutralizing broth. Swabs were stored on ice, packed into coolers, and shipped overnight to collaborators at the University of Florida for processing. Swabs were tested for *Listeria* species, *L. monocytogenes*, total coliforms, *Escherichia coli*, and total aerobic count.

For retail partner 1, 141 swabs were collected and processed. Only one sample (0.7 percent) tested positive for *E. coli*. Approximately 32 percent (45/141) of the swabs tested positive for *Listeria* species (Figure 3.1). No swabs tested positive for *L. monocytogenes* from any of the contact surfaces. Interestingly, five of the seven surfaces tested positive for *Listeria* species at least once during the study. *Listeria* species were detected in 100 percent (19/19) of the swabs collected from the foam contact surface across all stores. The foam contact surface (Figure 3.0) was observed in whole cantaloupe displays, where the melons were placed on top of the foam to provide cushioning and to limit bruising (since most displays were constructed of wood or plastic). Surfaces associated with whole cantaloupe contact had a higher prevalence of *Listeria* species (~74 percent, 28/38) compared with surfaces associated with fresh-cut cantaloupe contact (~18 percent, 17/95). The frequency of *Listeria*–positive samples varied by time point. For example, the frequency of *Listeria*–positive samples decreased after mid-day cleaning. Similarly, most surfaces also showed a decrease in coliform counts after the mid-day cleaning (Figure 3.2). Surfaces associated with whole cantaloupe display (foam and sides of display structures), which were not part of the mid-day cleaning, had the highest coliform counts during the study.

For retail partner 2, 200 swabs were collected and processed. Only whole cantaloupe contact surfaces were sampled (none for fresh-cut cantaloupe). No samples tested positive for *E. coli*. Approximately 33 percent (65/200) of the swabs tested positive for *Listeria* species. All surfaces were *Listeria*–positive at least once (6/6; Figure 3.3). One *L. monocytogenes*–positive sample was found initially but was negative upon retest three consecutive times (demonstrating the sporadic nature of *Listeria* in environments). Plastic carts had the lowest prevalence of *Listeria* species but were cleaned and sanitized daily. The next lowest prevalence of *Listeria* species was from external displays (wood and RPCs) where cantaloupe were in indirect contact with surfaces. The three contact surfaces that were in direct contact with cantaloupes at retail partner 2 were mesh (30 percent), plasticor (54 percent), and styrofoam fruit cups (46 percent). Interestingly, those three contact surfaces were only cleaned and sanitized on an as-needed basis. Additionally, the frequency of *Listeria*–positive samples decreased toward the end of the day (Figure 3.4). Possible reasons for this reduction in

positive samples include less customer traffic, and time of day that workers typically re-stock and/or new workers arrive (i.e., shift change; also the second shift focuses more on cleaning and sanitizing, and tidying the store). Unlike at retail partner 1, none of the contact surfaces at retail partner 2 had drastically higher frequencies of *Listeria*–positive samples; *Listeria* species prevalence on all six contact surfaces at retail partner 2 was less than 50 percent, compared with 100 percent prevalence on foam at retail partner 1 (Figure 3.5).

Additionally, a survey was designed to determine the risk perceptions and risk rankings surrounding washed and unwashed cantaloupe, as well as retail handling and supplier procedures. Recruitment began by identifying the largest retail and wholesale chains by total sales. Retail and wholesale chains were then chosen based on three criteria: they sold products directly to the public at retail or wholesale, had a significant number of stores in the U.S., and were likely to sell fresh produce. Employees of those chains who were listed in the International Association for Food Protection (IAFP) membership directory were then identified. Twenty individuals were chosen based on their employer and familiarity with the company's produce handling procedures. These individuals were emailed with requests to take the survey over the phone or online through SurveyMonkey; all participants chose to take the survey online. Results were analyzed using the built-in analysis tools provided by SurveyMonkey as well as Microsoft Excel. In total, eight individuals participated in the survey.

The survey results indicated that cantaloupes are seen as a moderate- to high-risk product. Participants were asked to rank the safety of various products on a 5-point scale, with 1 being low risk and 5 being high risk. The average risk rankings obtained were as follows: cantaloupes, 3.875; tomatoes, 3.375; cabbage, 2.875; and sweet potatoes, 2. Additionally, eastern and western cantaloupes were observed to have a similar risk, as ranked by survey participants. The survey found that washing had a significant effect on the perceived safety of cantaloupes, with the risk for unwashed cantaloupes ranked at 4.25 compared with unwashed cantaloupes at 3.125. Interestingly, all eight participants (100 percent) from the retail organizations stated that washing may increase the risk of foodborne pathogen contamination if not done properly. In fact, six (75 percent) of the participants claimed their employers required cantaloupe suppliers to provide washed product. Five (62.5 percent) of the participants said their employers changed cantaloupe washing guidelines after the 2011 and 2012 cantaloupe-borne outbreaks. When asked for further details on washing policies, some followed third party standards (e.g., Global Food Safety Initiatives [GFSI]), while others followed the FDA guidelines for cut melon or simply required sanitizer use. For example, six participants (75 percent) said their employer required the use of sanitizers in the rinse water in order to purchase cantaloupe from suppliers.

In June 2017 the PI presented interim research results at the CPS Research Symposium in Denver, Colorado, to 325 attendees.

The project focused only on cantaloupes and did not benefit commodities other than specialty crops.

The project partners are CPS and the Virginia Polytechnic Institute and State University (Virginia Polytech). CPS managed the project and the P) at Virginia Polytech performed the research studies in conjunction with two Co-PIs at two subcontractor universities. The PI supervised all three objectives of the project and communicated the project progress and findings to CPS. The Co-PI at the University of Florida analyzed swabs collected from melon field packing and retail environments and worked on the survival experiments for *Salmonella* and *L. monocytogenes* on contact surfaces. The Co-PI at North Carolina State University collected

retail samples from the retail partners and performed the retail survey and interviews. In addition, the project benefited from the input and cooperation of two U.S. retail partners that allowed researchers to carry out environmental monitoring at their retail locations.

Goals and Outcomes Achieved

Activities completed to achieve these goals included (i) environmental sampling of contact surfaces in field-pack melon operations, which entailed processing of swabs, detection and isolation of organisms; (ii) determination of *Salmonella* and *L. monocytogenes* transfer between contact surfaces (field-pack and retail contact surfaces) and cantaloupe; (iii) *Salmonella* and *L. monocytogenes* survival studies on contact surfaces; (iv) evaluation of each sanitizer on *Salmonella* and *L. monocytogenes* survival on selected contact surfaces; (v) environmental sampling of contact surfaces in multiple and multi-state retail locations; (vi) surveying retail personnel to assess melon handling practices; and (vii) communicating guidance for safe handling of field-pack cantaloupe to stakeholders.

Long-term outcome measures include publication of three peer-reviewed journal articles, one for each of the main project objectives. The team submitted these articles for peer review during 2018.

The original proposal set out to (i) determine metrics on pathogen transfer between cantaloupe melons and nine contact surfaces, representing six cross-contamination points (gloves, knives, pack tables, rags, brushes, and bins); (ii) assess the microbial load of each contact surface in field-pack cantaloupe operations and rank the contact surfaces in terms of relative risk for cross-contamination; and (iii) develop metrics and guidance for the safe handling of field-pack cantaloupe.

The team determined transfer coefficients for *Salmonella* and *L. monocytogenes* between cantaloupe and all the contact surfaces except for cardboard (bins). The contact surfaces tested included cotton (gloves, rags), rubber (gloves), nitrile (gloves), stainless steel (pack tables, knives), polyethylene (pack tables), and plastic bristles (brushes). Cardboard bins were not tested because only single-use, new cardboard was used in field-pack operations. The microbial load of each contact surface used in several field-pack operations was assessed. However, a ranking of the contact surfaces was not achievable since the data demonstrated that pathogen transfer was extremely low and no significant differences were observed among contact surfaces, except for the rubber gloves compared with the other glove types. Thus, the data did not support a ranking system for contact surfaces at the field-pack level. The metrics and guidance developed in this project have initially been communicated through project results at various presentations, including to stakeholders and members at the California Melon Board meetings. The critical findings were that rubber gloves should be avoided in field-pack due to the high risk of pathogen transfer once they become contaminated or degraded over time; and that field-pack equipment should be cleaned and sanitized immediately after operations end since pathogen survival was better on fouled/dirty surfaces (i.e., do not wait until the next day's operations, or leave overnight). Also, the best way to prevent pathogen harborage (after cleaning) was to sanitize with an overnight application (i.e., the shorter (30 minute) application was not as effective); PAA was most effective against both pathogens if a short contact time is used during sanitation. Upon publication of these findings in peer-reviewed publications, the melon stakeholders can use the data and guidance in their food safety plans.

The transfer of *Salmonella* and *L. monocytogenes* from a contaminated cantaloupe to surface or contaminated surface to cantaloupe was low when using either a dry or wet inoculum. The transfer data highlighted the importance of using the most real-world "inoculum" application (dry versus wet inoculum). For example,

pathogen transfer rates were higher with cotton gloves when a wet inoculum was used, compared with a dry inoculum, due to the wet inoculum soaking into the cotton. Western cantaloupe production is typically very dry (due to the California and Arizona climates), and water is only used when cleaning and sanitizing surfaces post-operational run. Also, all surfaces are not created equal, and the risk of cross-contamination is not equally distributed. Some contact surfaces, such as foam, are more likely to harbor pathogens. Rubber gloves have higher transfer of *Salmonella* and *L. monocytogenes* compared with other contact surfaces such as nitrile gloves or stainless steel. Transfer of pathogens were also influenced by contact time and pressure; however, when standardized, similar results were observed. Additionally, fouled or dirty surfaces aided in transfer (or cross-contamination) of both pathogens, highlighting the importance of sanitation practices.

While both pathogen populations declined on contact surfaces over the 8 hours, pathogen survival was greater when contact surfaces were fouled versus clean. It is recommended that cantaloupe growers and packers do not leave dirty surfaces for prolonged periods of time, as this may increase pathogen harborage. Additionally, pathogen survival was greater when contact surfaces were inoculated using a wet versus dry inoculum, thus water should be avoided, or limited, if possible in dry environments. Experiments were performed to investigate sanitation of stainless steel with no treatment, a water treatment, chlorine treatment (150 ppm), and peroxyacetic acid treatment (80 ppm). Two contact times were selected: 30 minutes and 15 hours based on direct input from stakeholders. The most effective sanitation for fouled stainless steel was an overnight contact time (both chlorine and PAA were effective). It is important to note that when stainless steel is clean, a 30 minute contact time was effective (cleaned surfaces are easier to sanitize); however, stainless steel pack tables will rarely be clean after a full day of melon packing operations.

Contact surfaces at retail also impacted the likelihood of *Listeria* species frequency. For example, a foam contact surface used to cushion cantaloupe on display tables or bins had 100 percent *Listeria* spp. detection during longitudinal sampling. Also, contact surfaces in indirect contact with cantaloupe such as wood or plastic bins (RPCs), had significantly lower frequencies of *Listeria* spp. compared with contact surfaces in direct contact with cantaloupes. This may be a result of fouled surfaces promoting better survival of *Listeria* than clean or less dirty surfaces. In general, contact surfaces that were cleaned and sanitized had lower frequencies of *Listeria* species. Based on observation and interviews, sanitation protocols were very robust for fresh-cut cantaloupe and as a result the *Listeria* spp. prevalence was low. On the other hand, sanitation protocols were fluid and or non-existent for whole cantaloupe, and as a result the *Listeria* spp. prevalence on contact surfaces was significantly higher. Cleaning and sanitizing protocols must be in place for whole cantaloupe at retail. Sanitation “as needed” does not seem sufficient to limit the prevalence of *Listeria* spp. Surfaces should be changed frequently when cleaning and sanitizing is not possible. Lastly, it is important to note, uniformity of handling practices and contact surfaces may exist within retail chains, but retail chains differ markedly between each other. Several differences were observed between retail partner/chain 1 and 2, for example, with different contact surfaces or sanitation protocols.

The survey data indicated that washed cantaloupe was perceived to be a safer product than unwashed cantaloupe. The majority of participants said their employers (retail chains) required that suppliers provide washed product, despite the belief that improper washing can/may increase the risk of foodborne pathogen contamination. While this survey was limited by the number of participants, the results demonstrate the need for future work to focus on uniform handling of cantaloupe throughout the supply chain.

Major successful outcomes of the project include the following for each objective:

Objective 1. Transfer data for *Salmonella* and *L. monocytogenes* on eight field-pack contact surfaces was determined. Transfer was significantly higher for rubber gloves compared with all other field-pack contact surfaces. Based on observations and working with the industry, it appears that over time, due to wear, rubber gloves become cracked and allowed better attachment of pathogens. Also, less transfer of *Salmonella* and *L. monocytogenes* was observed between contaminated cantaloupe and surfaces (or contaminated surfaces and cantaloupe) with shorter contact times. Furthermore, less transfer of *Salmonella* and *L. monocytogenes* was observed between contaminated cantaloupe and surface (or vice versa) with smoother surfaces (e.g., stainless steel or nitrile gloves).

Objective 2. Pathogen survival was significantly greater on fouled than on clean surfaces, highlighting the importance of robust, frequent sanitation. The most effective sanitation protocol for fouled contact surfaces was an overnight application of either chlorine or PAA (to achieve significant reductions of both *Salmonella* and *L. monocytogenes* on contaminated, fouled surfaces compared with contaminated, clean surfaces or un-contaminated surfaces).

Objective 3. *Listeria* species were present in retail whole cantaloupe display environments (*Listeria* spp. prevalence was >30 percent for each retail partner). Retail contact surfaces in whole cantaloupe areas that were cleaned and sanitized on a regular basis (e.g., daily) had lower *Listeria* spp. prevalence (nearly four-fold), compared to those surfaces that had variable (or as needed basis) cleaning and sanitizing schedules. Foam had the highest frequency of *Listeria*–positive samples (100 percent) and, therefore, is not recommended for use in whole cantaloupe display, despite its ability to cushion product.

Beneficiaries

Key beneficiaries include the West Coast melon industry, specifically the California and Arizona cantaloupe industry. The cantaloupe industry in California and Arizona represents 90 percent of the U.S. cantaloupe acreage, and most producers are linked to the commodity groups represented by the California Cantaloupe Advisory Board and the California Melon Research Board. Indirectly, this project can benefit other specialty crop commodities that are field-packed (e.g., watermelon, cucumber, and squash). Additionally, retailers and other post-field-packing melon operators will gain insight into risk factors for transfer of pathogens to cantaloupe, and recommendations at the retail level such as the importance of a sanitation schedule for whole cantaloupe handling and display.

Beneficiaries include the ~55 melon growers and 35 melon grower/handlers in California. According to the 2012 Census of Agriculture, California leads the nation in cantaloupe production by acreage, volume, and value.

The PI presented project results to stakeholders at the California Melon Symposium in 2017 and 2018, and in both years the presentation was positively received. Attendance at these symposia consisted of 70–90 growers, packers, shippers, and agricultural professionals. The economic benefit of food safety and implementation of risk reduction strategies is difficult to assess and was not the focus on this project; however, all stakeholders the PI has interacted with have been very interested in the data, especially the California Melon Research Board members. Additionally, the two major multi-state U.S. retailers that were the confidential retail partners in this project welcomed the data.

The PI from Virginia Polytech presented final research results in June 2018 at the 9th annual CPS Research Symposium in Charlotte, North Carolina, to 300 symposium attendees. Interim results were presented previously in an oral presentation at the 2017 CPS Research Symposium in Denver, Colorado (325 attendees), and in a poster session at the 2016 CPS Research Symposium in Seattle, Washington (315 attendees). The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to discuss the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Project results were disseminated at industry meetings, and streamed through social media sources. Results were also made available online as follows:

1. Final report to CPS is posted on the CPS website: https://www.centerforproducesafety.org/grant_opportunities_awards.php
2. CPS works with the scientists to publish results in scientific journals. Publication dates occur after the project is completed. Abstracts and awards can be found on the CPS website.
3. The Board of Directors and members of the Technical Committee of CPS distribute a series of information briefs throughout the year on the website and through presentations, meetings and webinars. An example of this would be the "2017 CPS Symposium – Key Learnings" on the CPS website, available in both English and Spanish, at the following link: https://www.centerforproducesafety.org/key_learnings.php

The following websites provide additional resources on the final reports and symposium proceedings:
Center for Produce Safety: https://www.centerforproducesafety.org/resources.php
Produce Marketing Association: https://pma.com/topics/food-safety/center-for-produce-safety
Western Growers Association: https://www.wga.com/

Lessons Learned

It is challenging to sample for *Listeria* in retail environments due to the legal implications—what if a pathogen like *L. monocytogenes* is found? The PI and Co-PIs on this project are all statewide extension specialists and have strong connections with industry, and thus were able to navigate a challenging research experiment (environmental swabbing in stores), although it took a little longer than initially anticipated. The retail partners in this project were very patient and allowed the sampling to proceed because the team sampled "blind" and assured these project partners of confidentiality.

Cantaloupe production in California and Arizona is performed under dry conditions and in dry environments, and water is rarely used except for sanitation purposes. Therefore, in this project, the team performed experiments using a dry inoculum as well as using a wet inoculum that is traditionally reported in the scientific literature. The results obtained for the cotton contact surface inoculated with a dry versus wet inoculum varied significantly, which highlighted the importance of simulating real-world conditions in experiments. Also, the team had to reconsider a specific measure that was originally proposed, namely the ranking of relative risk for cross-contamination of the field-pack surfaces. Analysis of the data obtained during the project did not support a ranking.

Additional Information

See Attachment 1 for Figures 1.0 to 3.5

Presentations (includes all completed and submitted presentations associated with the project):

2016
Strawn, L.K. 2016. Control of Cross-Contamination in Field and Retail Handling of Cantaloupe. Center for Produce Safety Research Symposium – Lighting Round (Seattle, Washington).

2017
Pfuntner, R., L. Truitt, M.D. Danyluk, B. Chapman, and L.K. Strawn. 2017. *Salmonella* Transfer Potential during Field-pack Handling of Cantaloupe. International Association of Food Protection Annual Meeting (Tampa, Florida). Abstract P3-70.

Rupert, C., L.K. Strawn, M.D. Danyluk, L.M. Frederick, and B. Chapman. 2017. Control of Cross Contamination during Retail Handling of Cantaloupe. International Association of Food Protection Annual Meeting (Tampa, Florida). Abstract P3-39.

Strawn, L.K. 2017. Control of Cross-Contamination in Field and Retail Handling of Cantaloupe. Center for Produce Safety Research Symposium (Denver, Colorado).

Strawn, L.K. 2017. Control of Cross-Contamination during Field and Retail Handling of Cantaloupe: Progress Report Update. California Melon Symposium (San Diego, California).

2018
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CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 61	**Project Title:** Evaluation of Sanitizing Treatments for Sizer Carriers in Stone Fruit Packinghouses	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB15061	**Date Submitted:** December 2017
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Project Summary

The purpose of the project was to evaluate and improve sanitizing treatments for fruit sizer carriers in stone fruit packinghouses. In modern stone fruit packinghouses, fruit sizer carriers are small rollers/holders (often made of rubber and supported by plastic frames) for conveying washed and waxed fruit individually through optical sorters and automatic labelers for sizing, labeling, and packing. This section of the packing line typically is kept dry to protect electrical components and is not compatible to hosing with a large amount of water. The sanitation operation for carriers varies among packing facilities, with some cleaning (and possibly also some sanitizing) in place every shift. Field fruit surfaces often retain 10^3–10^5 microbes/cm^2 when arriving at packing facilities (Narsaiah et al., 2012; Pao and Brown, 1998). These natural microorganisms are common in the fruit production environment and their presence on fresh fruit does not normally represent a public health issue. Prior studies by the Principal Investigator's (PI's) research group have revealed that fruit packing operations, such as washing and waxing, can help to reduce fruit surface microbial load (Pao and Davis, 1999; Pao et al. 1999, 2000). However, a portion of the natural microflora will unavoidably enter and deposit, along with detached fruit waxes, over the subsequent fruit sizing and/or packing lines. Microbes can transfer between processing equipment and, in some cases, they develop biofilms and other food safety concerns (Allen et al. 2005; Kang et al., 2007; Pao and Davis, 2001). However, baseline microbial load data and information on the influence of packing operations on the microbial loads on sizer carriers in stone fruit packinghouses are lacking.

The objectives of this (one fruit season) study included: 1) surveying the levels of naturally occurring microflora on the fruit-contact surfaces of sizer carriers in commercial stone fruit packinghouses in California; 2) determining the growth potential of *Salmonella enterica* and *Listeria monocytogenes* on sizer carriers; and 3) investigating the potential of using humidity and temperature conditions to minimize pathogens on sizer carriers. The data obtained will be used to identify effective approaches on practical non-chemical sanitizing treatments for sizer carriers, which would be applicable to diverse fresh fruit packinghouses.

In 2014 the California tree fruit industry experienced two food safety events that were both associated with *Listeria monocytogenes* contamination. In an effort to help the California industry proactively review and, where needed, strengthen food safety programs, the research team collaborated with a major stone fruit grower and packer in California to carry out this project to evaluate sanitizing treatments for fruit sizer carriers in stone fruit packinghouses. This study evaluated the levels of naturally occurring microflora on sizer carriers of eight commercial stone fruit packinghouses in the Central Valley of California, and also investigated the influence of environmental conditions on the survival of *Salmonella enterica* and *Listeria monocytogenes* on the sizer carriers. Most of the packinghouse and laboratory work was completed in the summer of 2016. The research team performed an inoculation study on two types of carriers to observe the growth potential of *Salmonella enterica* and *Listeria monocytogenes* on clean and used carriers under 16

different environmental (four temperature and four humidity) conditions. Pathogen-resembling colonies isolated were identified to species level for confirmation. The study results suggested that both sizer carrier sanitation and environmental conditions (e.g., humidity and temperature combinations) can be beneficial in minimizing microbial contamination of packing lines and food-contact surfaces. The general practice used in California stone fruit packinghouses for cleaning sizer carriers was shown to be capable of significantly reducing potential bacterial contamination introduced from stone fruit and/or handling operations. Furthermore, this study demonstrated that some environmental conditions, such as the treatment combination of 75% humidity and 40°Celsius, can be beneficial in minimizing microbial contamination of packing lines.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Key activities and tasks associated with Objective 1 included environmental sampling and documenting sizer carrier sanitation in the packinghouses. Environmental swabs with phosphate buffer were used individually to sample 192 sizer carriers in eight stone fruit packinghouses in the Central Valley of California during packing operations in the fruit season (June to August 2016). In each packinghouse, 12 randomly selected carriers were swabbed on the fruit-contact surfaces (approximately 30 cm^2) before and after routine equipment cleaning. The swabs were then transported on ice with neutralizing broth before plating within eight hours using three meter Petri film plates according to manufacturer instructions.

Key activities and tasks associated with Objective 2 included laboratory inoculation studies and determining pathogen growth potential on sizer carriers. To prepare inoculums, four serotypes of H2S positive *Salmonella enterica* (*S.* Enteritidis ATCC 13076, *S.* Montevideo ATCC 8387, *S.* Newport ATCC 6962, and *S.* Typhimurium ATCC 14028) and four strains of *Listeria monocytogenes* (ATCC7644, ATCC19115, ATCC43256, and ATCC51772) were maintained at 4°Celsius on tryptic soy agar (TSA). The cultures were transferred to tryptic soy broth and incubated for 22 to 24 hours at 35°Celsius. The cultures were then centrifuged, re-suspended, and pooled in sterilized, deionized tap water to obtain approximately 8.0 and 6.5 log CFU/milliliter inoculums for spot and immersion inoculations, respectively. Two brands of new sizer carriers were obtained from local equipment suppliers (Compac, Visalia, California; Aweta Americas Inc., Fresno, California), and two brands of used sizer carriers were supplied by stone fruit packinghouses (Gerawan Farming, Kerman, California; Abundant Harvest, Kingsburg, California). To determine pathogen growth potential, carriers were immersed in inoculum for 15 minutes before being air dried at room temperature (22 ± 2°C) for two hours, to achieve a surface contamination level at approximately 2.0 log CFU/cm^2 as determined by subsequent swab tests.

Key activities and tasks associated with Objective 3 included performing inoculation studies and evaluating environmental treatments for pathogen growth and survival. For the pathogen growth study, inoculated carriers were held at 22, 28, 34 or 40°Celsius under 65, 75, 85 or 95% humidity in environmental chambers (model 7000-10; Caron, Marietta, OH) for one, three, and six days before pathogen enumeration. For the pathogen lethality study, inoculated carriers were air-dried for two hours before held at 34 or 40°Celsius under 65, 75 or 85% humidity for monitoring pathogen reduction up to two days. To determine the potential lethality by environmental conditions, the fruit-contact surfaces (30 cm^2) of the sizer carriers were spot-inoculated with one milliliter of each inoculum in approximately 75 droplets before being air dried at room temperature for two hours, to achieve a surface contamination level at approximately 6.5 log CFU/cm^2.

Key results from the study were as follows:
Environmental swabs of 192 carriers from California commercial packinghouses indicated that routine cleaning significantly reduced total aerobic and coliform counts on carrier surfaces from 3.9±0.3 to 3.2±0.3 (P = 0.002) and 1.5±0.4 to 0.9±0.5 (P = 0.001), respectively, but yeast and mold counts were not significantly reduced ($P \geq 0.05$) (Attachment 1, Figure 1). The survival of inoculated pathogens on clean and used (non-cleaned; with deposited wax, fuzz, etc.) sizer carriers was influenced by incubation humidity (65, 75, 85 or 95%), temperature (22, 28, 34 or 40°Celsius), pathogen types, and carriers. *Salmonella* and *Listeria* declined to ≤0.0 log CFU/cm^2 from ~2 log CFU/cm^2 (initial contamination level) after one day of exposure to 65% humidity at 40°Celsius, 75% humidity at 34°Celsius, or 85% humidity at 40°Celsius, regardless whether the carriers were new or had been used commercially. However, at 95% humidity, *Salmonella* counts persisted over six days at 34°Celsius on used carriers. When new carriers were inoculated with pathogens at approximately 6 log CFU/cm^2, a ≥3-log reduction was reached in four hours under 75 or 85% humidity at 34 or 40°Celsius (Figure 2). A ≥5-log lethal effect was observed in four hours under conditions of 75% humidity and 34°Celsius for *Salmonella*, 65% humidity and 40°Celsius for *Listeria*, and 75% humidity and 40°Celsius for both *Salmonella* and *Listeria* (Figure 2). No significant growth ($P > 0.05$) of either pathogen was observed under all experimental conditions on clean or used sizer carrier surfaces. The results suggest that both sizer carrier sanitation and environmental conditions (e.g., humidity and temperature combinations) can be beneficial in minimizing microbial contamination of packing lines and food-contact surfaces. The research team recommends additional studies to explore the potential of applying moderate, yet lethal, temperature and humidity conditions to combat microbial contamination on produce- and food-contact surfaces.

In June 2016, the PI gave an oral and poster presentation of the interim research results at the Center for Produce Safety (CPS) Research Symposium in Seattle, Washington to 315 attendees.

The project specifically focused on packinghouse operations for stone fruit and did not benefit commodities other than California specialty crops.

The project partners were the CPS and California State University, Fresno, as well as the California Fresh Fruit Association (CFFA). CPS managed the project and the California State University, Fresno, performed the research studies. The CFFA facilitated the communication among project investigators, stone fruit packing companies, and sizer carrier suppliers. The research team appreciated the contributions of sizer carriers by Compac (Visalia, California) and Aweta Americas Inc. (Fresno, California) and two California stone fruit packinghouses (Gerawan Farming and Abundant Harvest).

Goals and Outcomes Achieved

Activities that were completed included (i) evaluating the natural microbial loads on the fruit-contact surfaces of sizer carriers to establish baseline data on the efficacy of existing sanitation approaches; (ii) evaluating the growth potential of selected foodborne pathogens (*Salmonella enterica* and *Listeria monocytogenes*) on fruit sizer carriers; and (iii) evaluating potential clean-in-place sanitizing treatments (through humidity and temperature combinations) for fruit sizer carriers.

The project staff recruited and trained four undergraduate students, one graduate student, and one visiting scholar to support the experimental efforts. Tasks involved in the laboratory procedures include media preparation, microbial inoculation, sample preparation, plate counting, pathogen isolation, waste sterilization,

etc. Initial tests were performed to determine the adequate pathogen inoculum concentration to reach the desired artificial contamination of sizer carriers.

The project staff performed inoculation studies on two types of carriers to observe growth potential of *Salmonella enterica* and *Listeria monocytogenes* clean and used carriers under 16 different environmental (four temperature and four humidity) conditions. Pathogen counts were performed using agar overlay methods. Pathogen resembling colonies isolated from the experiment were identified to species level for confirmation.

The experimental plan for Objective 3 (Evaluating potential clean-in-place sanitizing treatments for fruit sizer carriers) was adjusted based on observations that inoculated foodborne pathogens (*Salmonella* and *Listeria*) were incapable of multiplying on the surface of sizer carriers. The observation prompted the team to identify potential temperature and humidity combinations as treatments for pathogen reduction on sizer carriers. This modification did not change the original goal and budget of the Objective 3.

The team completed all experiments, conducted data analysis and communicated results and conclusion to the industry partners of this study both orally and in writing.

Outcome measures were not long term. In the summer of 2017 the PI submitted a manuscript for publication based on the research findings of this project.

This project set out two goals: (1) to evaluate microbial loads on fruit-contact surfaces of sizer carriers through sampling eight stone fruit packing operations to establish the first baseline information on the efficacy of existing sanitation approaches, and (2) to evaluate potential clean-in-place approaches for sanitizing sizer carriers. Both goals were achieved in this study. First, baseline data on total aerobic bacteria, yeasts and molds, and coliform counts on sizer carriers before and after routine packinghouse cleaning (and sanitizing in some cases) were obtained. Results of this study suggested that the general sanitation practices for sizer carriers in California stone fruit packinghouses are capable of significantly reducing potential bacterial contamination introduced from stone fruit and/or handling operations. Second, a non-chemical approach to reduce pathogens on sizer carriers, through various combinations of humidity (65, 75 and 85%) and temperature (34 and 40°Celsius), was demonstrated to have potential as an effective sanitizing treatment.

The project staff worked closely with industry collaborators and completed all proposed experiments within the project timeframe. Key baseline data gathered include (i) the microbial loads on fruit-contact surfaces of sizer carriers in stone fruit packing operations before and after cleaning, which demonstrated the efficacy of existing sanitation approaches; and (ii) the survival of inoculated foodborne pathogens (*Salmonella* and *Listeria*) on sizer carriers exposed to various humidity and temperature combinations, which determined that a ≥3-log reduction was reached in four hours under 75 or 85% humidity at 34 or 40°Celsius, and a ≥5-log lethal effect was observed in four hours under conditions 75% humidity and 40°Celsius for both *Salmonella* and *Listeria*. These results may help the packinghouse industry with microbial control efforts.

Major successful outcomes for the project include the collection of the first baseline data on microbial loads on fruit-contact surfaces of sizer carriers in stone fruit packinghouses in California. Analysis of the microbial results suggested that the current general sanitation practices used for cleaning sizer carriers are capable of significantly reducing potential bacterial contamination introduced from stone fruit and/or handling

operations. Furthermore, the project demonstrated that treatment of sizer carriers with moderate environmental conditions, such as the combination of 75% humidity and 40°Celsius, can be beneficial in minimizing potential pathogen contamination of packing operations.

Beneficiaries

The specialty crop beneficiaries of this project are packers of fresh stone fruit in California and other growing regions (Pacific Northwest and Northeastern United States) as well as the stone fruit industries in these regions. California produces 95% of the peaches, plums, and nectarines harvested for fresh consumption in the U.S. (source: California Fresh Fruit Association). Also, approximately 25 to 30% of California's annual production of stone fruit is exported to more than 35 countries. The combined farm gate value of this crop is $900 million.

The project's accomplishments will primarily benefit the stone fruit packing industry, including the industry collaborators and equipment suppliers, and members of the CFFA. The California Fresh Fruit Association (formerly the California Grape & Tree Fruit League) is a voluntary, nonprofit agricultural trade association that represents California's fresh fruit industry.

The PI from the California State University, Fresno, presented final research results in June 2017 at the 8th Annual CPS Research Symposium in Denver, Colorado, to 325 symposium attendees. Interim results were presented previously in a poster session at the 2016 CPS Research Symposium in Seattle, Washington to 315 attendees. The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to critique the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Lessons Learned

The positive results of this study suggested that the current general sanitation practices for cleaning sizer carriers in California stone fruit packinghouses are capable of significantly reducing potential bacterial contamination introduced from stone fruit and/or handling operations. One positive experience was the cooperation of the packinghouses to participate in this study.

The original experimental plan for Objective 3 was to test antimicrobial solutions for reducing inoculated pathogens on sizer carriers. However, part way through the Objective 2 experiments the project staff observed that the pathogens (*Salmonella* and *Listeria*) inoculated at a low level did not survive and were incapable of multiplying on the surface of the sizer carriers, and that "natural death" seemed to be promising for reducing pathogen contamination on the sizer carriers. Therefore, the project staff adjusted Objective 3 to identify potential temperature (~22 to 40°Celsius) and relative humidity (~65 to 85% relative humidity) treatments for non-chemical reduction of pathogens inoculated at a high level on sizer carriers. As a result of this change in direction the team then demonstrated that moderate environmental conditions, such as the combination of 75% humidity and 40°Celsius, can be beneficial in minimizing potential pathogen contamination of packing lines.

Additional Information

See Attachment 1 for Figures 1 and 2.

Project results will be disseminated at industry meetings, and streamed through social media sources. Results will also be made available online as follows:

1. A final report submitted to CPS has been posted on the CPS website: http://www.centerforproducesafety.org/grant_opportunities_awards.php.
2. CPS worked with the scientists to publish results in scientific journals. Publication dates occur after the project is completed. Abstracts and awards can be found on the CPS website.
3. The Board of Directors and members of the Technical Committee of CPS distribute a series of information briefs throughout the year on the website and through presentations, meetings and webinars. An example of this would be the "CPS 2016 Research Symposium Key Learnings" on the CPS website at the following link: http://www.centerforproducesafety.org/amass/documents/document/365/CPS%202016%20Key%20Learnings.pdf.

The following websites provide additional resources on the final reports and symposium proceedings:
Center for Produce Safety: http://www.centerforproducesafety.org/resources.php
Produce Marketing Association: http://pma.com
Western Growers Association: http://www.wga.com/

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CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 62	**Project Title:** Microbial Food Safety Risks of Reusing Tail Water for Leafy Green Production	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB15062	**Date Submitted:** December 2018
Recipient Contact: Bonnie Fernandez-Fenaroli	**Telephone:** (530) 554-9761	**Email:** bonnie@centerforproducesafety.org

Project Summary

Although vegetable growers have made much progress in reducing water run-off (or tail water) on the California Central Coast by increasing the acres irrigated by driplines, overhead sprinklers are needed for germinating and establishing crops and for watering high-density leafy greens such as spinach and baby greens. Many Central Coast ranches irrigate with tail water from sediment basins, reservoirs, and underground pumping systems. Tail water results in run-off that can transport significant amounts of nutrients, sediments, pesticides, and microorganisms into the rivers, creeks, and estuaries draining into the Monterey Bay National Marine Sanctuary. Regulatory pressure from the Central Coast Regional Water Quality Control Board is increasing and the Board emphasizes conservation and improvements to surface water quality. Reusing tail and drainage water would help growers meet regulatory targets. Currently, growers are reluctant to irrigate crops with tail water due to a lack of information on the microbial food safety risks. This project set out to evaluate the food safety risks of using tail water for irrigating leafy green crops using conventional irrigation and production practices.

The Central Coast of California faces severe restrictions on water supplies caused by periodic droughts such as the most recent four year drought from 2013–2016. Growers in this region rely almost exclusively on ground water for irrigating crops. As ground water levels continue to decline near the coast, seawater intrusion into coastal aquifers has accelerated. Reusing tail water for irrigation of crops would help conserve ground water, thereby protecting underground aquifers from seawater contamination. Although many farms on the Central Coast have infrastructure, such as retention basins and pumping plants, to capture and reuse tail water, most growers are reluctant to use tail water for irrigation of food crops due to concerns of food safety risks from microbial human pathogens such as Shiga toxin–producing *Escherichia coli* and *Salmonella*. Few studies have evaluated the microbial food safety risks of reusing tail water for irrigation of leafy vegetable crops. Salinity and nutrients have been monitored in agricultural drainage water (surface run-off and tile drainage), but few studies have focused on the microbial ecology of this water. Most microbial studies have focused on sewage water that is recycled and has a disinfection step before the water is applied to food crops. Tail water from surface run-off typically is high in nutrients, such as nitrogen and phosphorus, has high turbidity and suspended solids, and can have significant concentrations of pesticides and microorganisms. Generic *E. coli* is frequently present in irrigation run-off but is infrequently correlated with the presence of foodborne pathogens. Thus, the objectives of this project were to: 1) monitor, characterize, and quantify microbial populations in run-off water from Central Coast vegetable fields; and 2) evaluate the risk of using this water source for the production of lettuce and other leafy green crops by quantifying survival of microorganisms during simulated reuse applications.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Key activities performed that were associated with Objective 1 (Characterize the chemical, physical, and microbiological composition of tail water from coastal vegetable fields) included the following:

Six sites (A, B, C, D1, D2, and E) (Attachment 1) were established for monitoring tail water on five commercial farms located in the northern and southern regions of the Salinas Valley. Water samples were collected monthly from tail-water retention basins and wells at each farm beginning in March 2016 and ending in March 2017. During the irrigation season, an automated peristaltic pump was used to periodically sample water from the sprinkler pipe of operating sprinkler systems into a 1-L bottle and a bottle containing a Moore swab. Physicochemical water characteristics were measured at each sampling time to evaluate a possible relationship with the microbial composition. Chemical and physical properties (i.e., pH, electrical conductivity, oxidation-reduction potential, turbidity, and temperature) of the water were measured in situ using a handheld multiprobe (YSI, Inc.), and collected samples were analyzed for additional nutrients and salinity constituents at the University of California, Davis (UC Davis) Analytical Laboratory. Water samples also were analyzed for generic *E. coli* and coliform bacteria by enumeration. Moore swabs were placed in the tail-water retention basins (reservoirs) and collected after three days for analysis of pathogenic Shiga toxin–producing *E. coli* (STEC) and *Salmonella*. Chemical, physical, and microbial data of tail water samples were analyzed for the six sites monitored monthly from March 2016 – March 2017.

The tail water had a basic pH (often greater than 8.0) and low turbidity, with a range of six to 212 mg/L of suspended solids. Salinity (and electrical conductivity) of the tail water was higher at sites located in the southern Salinas Valley (D1, D2, and E) where the salt content of the well water tended to be higher than in sites located in the north (A, B, and C), and where evaporation was highest. Nutrients such as phosphate-phosphorus (PO_4-P) and nitrate-nitrogen (NO_3-N) varied widely (PO_4-P: 0.07–15.8 mg/L; NO_3-N: 0.3–147 mg/L) among sites and during the year. Dissolved organic carbon also varied among sites, ranging from 1.9 to 32 mg/L. Generic *E. coli* exceeded 126 CFU/100 mL in approximately 20% of tail water pond samples and in two of 26 irrigation water samples. Differences were found in the concentration of generic *E. coli* among sites, but the differences could not be correlated with nutrient concentration of the water.

E. coli concentration was significantly higher at site D2 than at the other sites, and all the samples tested positive. *E. coli* was not detected in 42%, 38%, 31%, 23%, and 8% of the samples collected at site E, A, C, D1, and B, respectively. The *E. coli* geometric mean (n=12) remained below a level of 126 CFU/100 mL for all sites except D2 (1,016 CFU/100 mL). Single samples collected at site B, C, and D1 were equal or below 235 CFU/100 mL and met the California LGMA metric for water applied to edible plants. Single samples collected at site A and E were less than 576 CFU/100 mL and met the LGMA metric for water used for non-foliar application.

Salmonella could not be recovered from primary enrichment, but four out of 229 Moore swab secondary enrichment samples tested positive by real-time polymerase chain reaction (PCR) analysis (Table 1 – Attachment 1). *Salmonella* was retrieved from samples collected in reservoir D2 in August, September, and October 2016 and in reservoir B in October 2016. In total, four STEC were retrieved from the samples. *E. coli* O45 was retrieved from one primary enrichment in reservoir B in June 2016. After a secondary enrichment of the 229 Moore swabs, three different STEC were retrieved: two *E. coli* O145 from reservoir B in June and July 2016 and one *E. coli* O157 from reservoir D2 in February 2017.

Seasonal variation had no influence on the microbiological composition of the tail water. The major factor that influenced *E. coli* concentration in tail water was the location of the reservoir.

Key activities performed that were associated with Objective 2 (Evaluate risks of using tail water in lettuce and leafy green production by quantifying microbial survival during simulated application to soils used to grow leafy greens) included the following:

To evaluate the effect of different levels of nitrate and phosphate on the survival of *Salmonella* and *E. coli* O157:H7, tail water collected from all the reservoirs was inoculated with a cocktail of 5 log CFU/100 mL of *Salmonella* and *E. coli* O157:H7 and held for seven days at 19°C or the average temperature recorded in the tail-water reservoirs between March and October 2016. Both *Salmonella* and *E. coli* O157:H7 populations declined in tail water after seven days. The slowest rate of decline was recorded in tail water collected from reservoir E and the highest rate of decline was recorded in tail water collected from reservoir A. Levels of nitrate and phosphate were lowest in water collected from reservoir A and E. Although water from reservoir D2 had the highest level of phosphate and water from reservoir D1 had the highest level of nitrate, *Salmonella* and *E. coli* O157 populations in D1 and D2 water were lower after seven days than in E water.

The incubation experiments with tail and well water collected from site C also showed that nutrients (N and P) had no significant effect on the survival of generic *E. coli*. Generic *E. coli* populations declined rapidly in tail water during the first week after inoculation. In contrast, generic *E. coli* populations declined more slowly in inoculated well water, presumably due to less competition from other microbial species.

In soil, *Salmonella*, generic *E. coli*, and *E. coli* O157:H7 had the same rate of decline regardless of the water carrier (MilliQ, irrigation or tail water) used for inoculation. Lettuce seeds, which were planted in the contaminated soil in containers, germinated to reach cotyledon stage at day 28, with an extremely low rate of germination (0 to 1%). Cotyledons were collected and pooled from each container separately without touching the soil. The inoculated pathogen could not be enumerated in any of the cotyledon samples and was rarely detected by enrichment. Generic *E. coli*, *E. coli* O157:H7, and *Salmonella* populations declined more rapidly on the plant surface than in soil, and with higher variability at each sampling time point. The inoculated bacteria suspended in MilliQ water survived slightly longer on the plant surface than those bacteria suspended in the other water sources, with an average decline of 2 log CFU/leaf after seven days; survival for bacteria suspended in tail and irrigation water was identical, with an average decline of 3 log CFU/leaf after seven days.

The Principal Investigator (PI) presented interim research results at the 2017 Center for Produce Safety (CPS) Research Symposium in Denver, Colorado, to 325 attendees.

This project only benefitted specialty crop commodities.

The project partners are the CPS and the University of California Cooperative Extension (UCCE). CPS managed the project and the PI at UCCE, in collaboration with the Co-PI at UC Davis, performed the water sampling and research studies. The researchers at UC Davis provided guidance on the procedures used for the monitoring phase of the project (Objective 1) as well as the incubation studies (Objective 2). They conducted the microbial analyses for generic *E. coli* and coliform bacteria, identified the presence of pathogenic bacteria

using PCR analysis; completed the incubation studies; and were also instrumental in conducting the data analysis.

Goals and Outcomes Achieved

The approved project initially had three goals but, due to reduced co-funding for the project from the California Leafy Greens Research Program, the project focused on two goals, both of which were achieved during the project timeline. Associated activities included (1) characterization of chemical, physical, and microbiological properties of tail water from vegetable fields on the Central Coast, and (2) determination of whether tail water increases the survival of *E. coli* and *Salmonella* in soil (used to grow leafy greens). Interim results have been disseminated to stakeholders at professional and industry meetings, and final results will be summarized into reports that will be available for stakeholders to download from UCCE and CPS websites. In 2018, project results were communicated to more than 50 leafy green growers at the 2018 Irrigation and Nutrient Management Meeting (coordinated by UCCE), and at the Annual Meeting of the California Leafy Greens Research Program, attended by more than 50 leafy greens industry representatives, including growers (see Additional Information). In this way the project results have been used to educate industry and inform LGMA guidelines.

Both short-term and long-term progress was made towards achieving the outcomes of educating the industry and informing the California LGMA guidelines. Presentations of interim results were made at both professional and industry meetings (see Additional Information). The final report prepared for CPS will be available for stakeholders to download from the CPS website and the UCCE–Monterey County website. Downloads of the report and presentations will be assessed after one year. The research team also intends to disseminate results in at least one article in a scientific journal for peer review as well as articles in trade magazines (e.g., American Vegetable Grower, California Association of Pest Control [CAPCA] Adviser) and a posting on the Salinas Valley Agriculture blog. One long-term outcome would be the adoption of the results in the next update to the LGMA guidelines.

The original proposal set out to (1) characterize chemical, physical and microbiological properties of tail water from vegetable fields on the Central Coast of California; (2) determine whether tail water increases the survival of *E. coli* and *Salmonella* in soil; and (3) reduce the cost of disinfecting tail water carrying high loads of suspended sediments. The first two goals were achieved during the project period. The physical, chemical, and microbial properties of tail water from five representative Salinas Valley farms were characterized during an entire year. The presence of pathogenic *E. coli* (STEC, O157:H7) and *Salmonella* was evaluated in 229 samples from tail-water reservoirs and 26 samples from operating sprinkler systems. The project determined that tail water did not increase the survival of *Salmonella* or *E. coli* O157:H7 in soil or on growing lettuce plants. Due to a significant decrease in matching funds received for the project from the California Leafy Greens research program, the third goal was not initiated and could not be accomplished.

Before conducting the project, there were no comprehensive studies that characterized the chemical, physical, and microbial properties of agricultural tail water on the Central Coast of California. In addition, few studies had evaluated whether the constituents of tail water enhance the survival of human pathogenic microbes in water or soil and on leafy green vegetables. Baseline data of chemical characteristics of tail water and prevalence of *Salmonella* and STEC in tail and irrigation water are presented in Table 1 and 2 (Attachment 1). This project achieved the targets of increasing the knowledge base about the potential food safety risks of

reusing tail water for irrigation of leafy green crops, which will be used to educate the industry and inform LGMA guidelines.

The physical, chemical, microbial properties of tail water from five representative Salinas Valley farms were characterized during an entire year. Through the use of Moore swabs the presence of pathogenic *E. coli* (STEC, O157:H7) and *Salmonella* was evaluated in 229 samples from tail-water reservoirs and 26 samples from operating sprinkler systems. Two incubation studies were conducted to evaluate whether tail water enhances the survival of *E. coli* and *Salmonella* compared with well water. Two incubation studies were conducted to evaluate whether elevated concentrations of phosphate and nitrate prolonged the survival of *E. coli* in tail water. A growth chamber study was conducted to evaluate whether tail water prolonged the survival of pathogenic *E. coli* and *Salmonella* in the soil and on lettuce leaves

Beneficiaries

California specialty crop produce farmers, specifically leafy green growers, the consumers of California leafy greens, and shippers and handlers, will all benefit from the information generated from this project on the food safety of tail water. Potentially, water users on the Central Coast will benefit if growers can minimize tail water run-off by reusing the water for irrigation of leafy green vegetable crops.

The information generated by this project would immediately benefit nearly 2,000 growers of leafy greens and industry representatives in the Central Coast of California. According to the LGMA, Monterey County in the Central Coast is the largest county of leafy greens production in California, and in 2015 produced over 100,000 acres of lettuce valued at $1.5 billion. The project information will indirectly benefit consumers of leafy green vegetables due to the implementation of improved food safety practices. Increased reuse of tail water from farms will benefit users of surface water bodies by improving water quality.

The PI from the UCCE presented final research results in June 2018 at the 9th annual CPS Research Symposium in Charlotte, North Carolina, to 300 symposium attendees. Interim results were presented previously in an oral presentation at the 2017 CPS Research Symposium in Denver, Colorado (325 attendees), and in a poster session at the 2016 CPS Research Symposium in Seattle, Washington (315 attendees). The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to discuss the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Project results will be disseminated at industry meetings and streamed through social media sources. Results also will be made available online as follows:

1. Final report to CPS is posted on the CPS website: https://www.centerforproducesafety.org/grant_opportunities_awards.php
2. CPS works with the scientists to publish results in scientific journals. Publication dates occur after the project is completed. Abstracts and awards can be found on the CPS website.
3. The Board of Directors and members of the Technical Committee of CPS distribute a series of information briefs throughout the year on the website and through presentations, meetings and webinars. An example of this would be the “2017 CPS Symposium – Key Learnings” on the CPS website, available in both English and Spanish, at the following link: https://www.centerforprod.org/key_learnings.php

The following websites provide additional resources on the final reports and symposium proceedings:
Center for Produce Safety: https://www.centerforproducesafety.org/resources.php
Produce Marketing Association: https://pma.com/topics/food-safety/center-for-produce-safety
Western Growers Association: https://www.wga.com/

Lessons Learned

Key lessons learned are that it was very valuable to the project to have staff on campus that could conduct in-depth microbial analysis of water samples using PCR methodology, and to have staff located in the study area so that they could collect samples of tail water in a timely manner. The project benefitted from the high number of samples collected (>250) by the project staff. The project team also demonstrated that reducing the holding time of water samples provided a more realistic analysis of bacteria levels.

The project results demonstrated that *E. coli* survival in tail water was often less than in well water, and that high nutrient and sediment concentrations in tail water did not enhance the survival of these bacteria.

Additional Information

Project findings were presented at industry and professional meetings, as listed below:

Cahn M., Harris L., Moyne A., Koike S., Murphy L. (2016) Microbial food safety risks of reusing tail water for leafy green production. CPS Research Symposium, June 28-29, Seattle, WA.

Cahn M., Harris L., Moyne A., Koike S., Murphy L. (2017) Microbial food safety risks of reusing tail water for leafy green production. CPS Research Symposium, June 20-21, Denver, CO.

Moyne A.L., Murphy L.A., Cahn M.D., Koike S.T., Harris L.J. (2017) Microbial quality of tail water in the California Central Coast Salinas Valley. Abstract P3-230. Annual meeting of International Association for Food Protection (IAFP), July 9-12, Tampa, FL.

Moyne, A., Murphy, L.A., Koike, S.T., Cahn, M.D., Harris, L.J. (2018) Microbial food safety risks of reusing tail water for production of leafy greens. University of California Cooperative Extension (UCCE). 2018 Irrigation and Nutrient Management Meeting, February 13, Salinas, CA. Available at: http://cemonterey.ucanr.edu/files/278816.pdf.

Moyne, A., Murphy, L.A., Koike, S.T., Cahn, M.D., Harris, L.J. (2018) Microbial food safety risks of reusing tail water. California Leafy Greens Research Board, 2017-18, Annual Research Conference, March 27, Pismo Beach, CA.

USDA Project No.: 63	Project Title: Comparative genomics analysis and physiological assessment of the avirulent *Salmonella* surrogate relevant to produce safety	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB15063	**Date Submitted:** December 2018
Recipient Contact: Bonnie Fernandez-Fenaroli	**Telephone:** (530) 554-9761	**Email:** bonnie@centerforproducesafety.org

Project Summary

Coliforms and generic *Escherichia coli* are poor predictors of behavior of human pathogens (such as *Salmonella*, pathogenic *E. coli* and *Listeria*) in the crop production environment. Accurate models of *Salmonella* behavior in the production environment must be built based on experiments conducted with *Salmonella*, and not based on data from distantly related surrogates like generic *E. coli*. This requires availability and careful characterization of "disarmed" strains of *Salmonella* that could be used for on-site research. This study set out to develop robust tools for modeling the behavior of these outbreak strains in the pre- and post-harvest production environments. The purpose of this project was to carry out comparative genomic and physiological characterization of the outbreak strains under production conditions and to compare them with a nonvirulent strain of *Salmonella* developed by the research team to be suitable for on-site studies as an indicator organism.

Outbreaks of produce-borne salmonellosis have been disproportionately associated with only a few of the 2,500 *Salmonella* serovars (or strains). It is important to define what makes these strains more likely to occur and persist in the fruit and vegetable production chain so that their behavior under conditions relevant to the produce industry can be accurately modeled, with the aim of reducing the occurrence and persistence of pathogens in the production environment or disrupting their virulence. Comparative genomics analysis of the outbreak strains will reveal features and potential physiological adaptations that may be responsible for the persistence of these strains in the production chain (soil, water, plant surfaces and tissues). This information will be integrated with on-going characterization of the avirulent surrogate strain of *Salmonella* Typhimurium (*S.* Typhimurium) to determine to what extent it could be used to model behaviors of the outbreak strains.

This project built upon the 2012 Specialty Crop Block Grant Program (SCBGP) Project 64: *Avirulent Salmonella strains and their use to model behavior of the pathogen in water, composts, in and on vegetables*. The previous project resulted in the construction of several avirulent strains, including a surrogate strain of *Salmonella* suitable for on-site experiments. That strain was selected as the surrogate strain for this project. The strain lacks all five *Salmonella* pathogenicity islands and its virulence plasmid; the strain is sensitive to antibiotics and is free of features increasing its resistance to antibiotics. The strain was designed to fail polymerase chain reaction (PCR)–based *Salmonella* detection approaches but can be identified using culture-based techniques. The surrogate strain can be distinguished (using PCR or culture-based techniques) from the wild type *Salmonella* because of its loss of function *phoN* mutation. The surrogate strain was shown to be avirulent in two animal models and approximates reasonably well the behavior of fully virulent strains under tested production-relevant conditions. However, the extent to which this surrogate mimics the behavior of the *Salmonella* strains linked to produce outbreaks had not been tested. This project determined the suitability of the surrogate strain for modeling the behavior of the outbreak strains of pathogens in pre- and post-harvest production environments.

Project Approach

Key activities completed for Objective 1 (phenotypic characterization of the avirulent surrogate *Salmonella* strain and comparison to outbreak *Salmonella* serovars) included assessment of the ability of the avirulent surrogate *Salmonella* to form biofilms, to survive in soil and water, and to colonize plants. These characteristics also were determined for outbreak *Salmonella* serovars in order to compare the phenotypes of outbreak serovars for characteristics relevant to the production environment. The avirulent *Salmonella* surrogate is nonpathogenic due to the lack of structural virulence genes, yet the deletion of five virulence islands and a virulence plasmid do not change the behavior of the surrogate in the pre- and post-harvest production environment. Biofilm formation by the wild-type strain *S.* Typhimurium was more extensive on polypropylene than on polystyrene. The avirulent surrogate formed approximately twice as much biofilm as the parental wild-type strain on the two plastics; however, it showed no difference in biofilm formation from the wild type on stainless steel. These results suggest that the surrogate may exhibit improved survival in response to treatments or conditions where biofilm is protective, which may lead to underestimation (but not overestimation) of effects. Susceptibility to heat shock and disinfection with Pheno-Tek II (a detergent) were similar in the avirulent surrogate and the wild-type *Salmonella*. Heat stress for one, two, or three hours induced a 100-fold decrease in colony-forming units (CFU) per ml. Pheno-Tek II at 1:250, 1:500, and 1:1,000 dilution levels inhibited all growth of *Salmonella*. *Salmonella* levels increased by about 10,000-fold in tomatoes or cantaloupes at three days and five days, respectively. The avirulent surrogate had slightly lower growth in green, but not red, tomatoes. Proliferation of *Salmonella* serovars Typhimurium, Agona, Braenderup, Javiana, Montevideo, Newport, and Poona in red tomatoes exhibited the most variability, with the highest growth in Agona and Braenderup. *S.* Typhimurium grew significantly better in green tomatoes than did all other tested serovars. Montevideo and Javiana achieved the highest levels of growth in cantaloupes, although results between trials were variable. On leaf surfaces, culturable populations of *Salmonella* declined over time. On spinach leaves, both the wild-type *S.* Typhimurium and the avirulent surrogate demonstrated a 91% decrease at day one after inoculation and further decreases three days after inoculation. All tested *Salmonella* strains, including the wild-type strain *S.* Typhimurium, the avirulent surrogate, and the produce-associated serovars Agona, Braenderup, Javiana, Montevideo, Newport, and Poona declined in abundance but were still detectable in soil for 14 days and in water for 7 days, the duration of experimental test periods. *Salmonella* abundance decreased 100-fold within two days in water and decreased another 100-fold after seven days in water. Overall, these results indicate that *Salmonella* virulence genes located on pathogenicity islands 1 to 5 and the virulence plasmid do not contribute to the persistence of this organism outside of animal hosts.

The activities completed for Objective 2 (characterization of the *Salmonella* pan-genome) included completing a pangenome analysis of publicly available *Salmonella* serovars to identify the core genes needed by all *Salmonella* serovars as well as the accessory genes found in serovars associated with produce-linked outbreaks of salmonellosis. The pangenome analysis of 2,098 high quality *Salmonella* genomes identified more than 31,000 genes. The grouping of serovars Typhimurium, Newport Group II, and Newport Group III were supported by overall genome content, while Newport Group I lacked high quality genomes to support its position as a separate serovar group. *Salmonella* serovar Typhimurium had an average of 4,628 genes per genome, while serovar Newport Group II had 4,554 genes per genome and Newport Group III had 4,413 genes per genome. The characterization of the presence/absence profile of genes across *Salmonella* genomes allowed the identification of the 724 genes shared by most members of the Newport Group III and 84 genes unique to its core (shared by all members). Since the team expected that the adaptation to plants is associated with Newport Group III, those genes involved in this phenotype should be exclusive or more frequent in this

group. The pangenome analysis also confirmed that the *Salmonella enterica* (*S. enterica*) Newport Group III strain C4.2 used for transposon mutant screening in Objective 3 was a typical representative of the genome content of Newport Group III serovars.

The activities completed for Objective 3 (functional characterization of genome by transposon sequencing [TnSeq] mutant screening) included a large-scale screening of *Salmonella* mutants to identify the functional genes that are required by *Salmonella* serovars Typhimurium and Newport Group III for growth in tomatoes. This analysis demonstrated that *Salmonella* strains require two key functions for survival in both animals and plants: lipopolysaccharide (LPS) and nucleotide biosynthesis. The production of LPS results in a coating over the outer membrane of pathogen cells, which essentially hides the pathogen from the host's defense systems because most immunity is based on the detection of unique identifying molecules on the exterior of the pathogen cell. In addition, it appears that the functions required by *Salmonella* for proliferation in tomatoes have little overlap with essential functions in phytopathogens. However, both *Salmonella* and phytopathogens require multiple genes for the biosynthesis of amino acids in order to grow within plant tissues that have low availability of amino acids, compared to growth in animal hosts.

Most genes in *Salmonella* serovar Newport that were selected for during persistence in tomatoes were shared with and similarly selected in *S.* Typhimurium. Many of these functions are involved in basal metabolism, including amino acid biosynthetic pathways, iron acquisition, and maintenance of cell structure. One exception was a greater need for core genes involved in purine metabolism in *S.* Typhimurium than in Newport. A new gene, *papA* (for plant associated protein A), which was unique to serovar Newport, also contributed to the fitness of a strain of serovar Newport in tomatoes. The *papA* gene present in 71 Newport Group III genomes was generally absent from other *Salmonella* genomes, but a homolog was detected in members of the *Enterobacteriaceae* family that can colonize both plants and animals.

This project did not enhance the competitiveness of non-specialty crops.

The project partners are the Center for Produce Safety (CPS) and the University of Florida (UF). CPS managed the project and the project team at UF performed the research studies.

Goals and Outcomes Achieved

This project had two performance goals: 1) to define the phenotypic difference between *Salmonella* serovars associated with produce-linked outbreaks and the avirulent surrogate developed through a previous SCBGP project, and 2) to determine the suitability of the avirulent surrogate for modeling the behavior of the outbreak strains in the pre- and post-harvest production environment. The activities completed included quantifying biofilm formation, survival in soil and water, and colonization of plants (green and red tomatoes, cantaloupes, spinach, cut lettuce leaves) for seven produce-linked *Salmonella* outbreak serovars and the avirulent surrogate strain. Both performance goals were achieved as the quantification of *Salmonella* serovar characteristics clearly showed that the avirulent surrogate behaves the same as the outbreak strains in its growth, while being non-pathogenic to human handlers. The surrogate has been determined as a suitable non-pathogenic model organism for use in testing and optimizing appropriate pre- and post-harvest production practices.

The avirulent *Salmonella* surrogate developed for this project (*Salmonella enterica* subsp. *enterica* serovar Typhimurium strain MHM112) is publicly available for purchase from the American Tissue and Culture Collection (ATCC), accession #BAA-2828. The Principal Investigator (PI) announced this result during the

presentation at the 2017 CPS Research Symposium in Denver, Colorado. During that presentation, audience participants immediately looked up the website and asked questions about the surrogate. Also, the PI was approached after the talk by several people who were interested in using the avirulent surrogate. The peer-reviewed publication describing the development and validation of the avirulent surrogate was published in mid-2016, and by the end of 2017 this paper had already been cited four times by other research labs. One of these recently published papers (see additional information) included the use of the *Salmonella* surrogate in testing the suitability of chitosan microparticles as an antimicrobial treatment for agricultural water, work that was performed at UF by a lab that obtained the surrogate from CPS directly before the public availability of strain. It is anticipated that many more citations will be forthcoming, when labs have had time to acquire, test, and publish results with the avirulent surrogate. Thus the project target of at least 10 new entities (each year) using the surrogate strain has a high likelihood of being achieved in the long term. While the ATCC does not provide information on purchases of the surrogate, the enthusiasm evidenced at the research symposium and by the wider scientific community demonstrates that this surrogate will be used by multiple entities involved in specialty crop microbiological safety research.

The phenotypic characterization of outbreak-associated *Salmonella* serovars and the avirulent *Salmonella* serovars was completed to document biofilm formation, survival in soil and water, and colonization of plants (green and red tomatoes, cantaloupes, spinach, cut lettuce leaves). The avirulent *Salmonella* surrogate behaved similarly to the virulent parental strain and thus serves as a valuable tool for testing protocols in the pre- and post-harvest production environment. The avirulent *Salmonella* surrogate developed for this project (*Salmonella enterica* subsp. *enterica* serovar Typhimurium strain MHM112) is publicly available from the ATCC accession #BAA-2828, and its genome is available from GenBank, accession #LONA00000000. The pangenome analysis was completed and identified functional genes unique to the genomes of produce-linked outbreak serovars. The large-scale mutant screening was completed and revealed functions needed by *Salmonella* serovars during the colonization of tomatoes. A novel gene associated with colonization of plants was also identified, which may serve as the topic of future research projects.

The results of the research conducted for this project, including the validation of the avirulent surrogate and the *Salmonella* pangenome analysis, have been published in four peer-reviewed journal articles (see additional information).

Previous funding from CPS supported the construction of a non-virulent surrogate strain of *Salmonella* that is suitable for on-site experiments. The current project demonstrated that this avirulent surrogate behaves like the parental virulent strain during growth in produce, persistence in soil and water, and in its sensitivity to heat and disinfectants. Thus, the team has validated the use of this fully avirulent, non-immunogenic, non-transgenic, and antibiotic-sensitive surrogate as a new tool in addressing Food Safety Modernization Act (FSMA) regulations.

In addition, the pangenome analysis of over 2,000 serovars of *Salmonella* revealed high diversity in the genomic composition across strains. Overall, the pangenome of 2,800 *Salmonella* genomes contained a total of 49,429 protein-coding genes, 5 percent (2,512) of which were found in almost every genome (99-100 percent) and represent the “core” *Salmonella* genome or functions essential to its growth in any habitat. The majority of genes, almost 90 percent, were each found in only a handful of the total genomes, reflecting the extraordinary genetic flexibility of *Salmonella*. These low-abundance genes are considered the “cloud”

genome which likely includes accessory functions that allow individual strains of *Salmonella* to adapt to different environments.

Genomes of the *Salmonella* serovar Newport, which has been associated with several produce-linked foodborne illness outbreaks, had a set of unique core genes that may be involved in adaptation to growth in plants. A massive parallel screening of mutants revealed that growth of *Salmonella* serovars Typhimurium and Newport required the production of LPS and nucleotide biosynthesis, regardless of the host. However, growth in plants required genes involved in the biosynthesis of amino acids, due to the low availability of amino acids in plant tissues. In addition, the novel gene *papA* that contributed to fitness of the strain in tomatoes was identified in *Salmonella* Newport. While the function of *papA* is currently unknown, homologues of this gene were found in *Enterobacteriaceae* capable of growth in both plants and animals.

Collectively, the pangenome analysis supports the idea that only a handful of *Salmonella* serovars can grow in produce because their genotype contains genes for adaptation to growth in plants. Furthermore, the discovery of this novel plant-associated *Salmonella* gene could be used as a marker gene to detect *Salmonella* that flourish in both plants and animals.

Beneficiaries

The key beneficiaries of this project include produce growers, the produce industry, and other scientists. Other research labs have already begun using the avirulent surrogate in studies that can benefit the produce industry by providing scientific guidance for the optimization and testing of production practices, ultimately improving food safety through the guidelines established by FSMA. Indirectly, the development of this avirulent *Salmonella* surrogate also has the potential to benefit anyone that consumes fresh produce.

The ability to model the behavior of *Salmonella* outbreak strains and more accurately predict the behavior of *Salmonella* under production environment conditions will benefit all California specialty crops. According to the 2012 Census of Agriculture there are 42,729 farms of produce crop growers representing $23.9 billion in sales in the state of California. The potential economic impact of this project to the specialty crop industry could be significant as it will allow the development of approaches for ensuring microbiological food safety that are uniquely adapted to a particular environment or situation. Currently, the United States Department of Agriculture - Economic Research Service estimates that salmonellosis outbreaks cost the United States economy $2.7 billion annually. Given that specialty crops are associated with only a fraction of these outbreaks, it is reasonable to estimate that having a useful surrogate for developing approaches to improve food safety will save the economy approximately $5 million annually.

The PI from UF presented the final research results in June 2018 at the 9th annual CPS Research Symposium in Charlotte, North Carolina, to 300 symposium attendees. Interim results were presented previously in an oral presentation at the 2017 CPS Research Symposium in Denver, Colorado (325 attendees), and in a poster session at the 2016 CPS Research Symposium in Seattle, Washington (315 attendees). The symposium participants included California regional and national growers and shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to discuss the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Lessons Learned

The most important lesson learned through this project was the benefit of changing the research approach to the mutant screening. Initially, the plan was to use a phage (virus) to insert mutations into particular genes identified through the pangenome analysis as potentially important to colonization of plants. However, by using a transposon (jumping gene) instead of a virus to create mutations, the team was able to examine mutations throughout the entire genome and therefore create a more robust analysis. This altered methodology also saved a substantial amount of money initially budgeted for lab supplies and personnel costs.

An unexpected outcome of implementing this project with the altered method for screening mutations was the discovery of a novel gene in *Salmonella* serovar Newport, which is required for growth of this serovar in tomatoes. Now that this gene can be identified, future studies may uncover the mechanisms for plant colonization provided by this gene. Ultimately, this knowledge may lead to innovative new techniques for preventing the spread of *Salmonella* in produce.

Additional Information

The avirulent *Salmonella* surrogate developed for this project (*Salmonella enterica* subsp. *enterica* serovar Typhimurium strain MHM112) is publicly available for purchase from the American Tissue and Culture Collection (ATCC), accession #BAA-2828 (https://www.atcc.org/en/Products/All/BAA-2828.aspx).

This project has resulted in five peer-reviewed publications:

de Moraes MH, Chapin TK, Ginn A, Wright AC, Parker K, Hoffman C, Pascual DW, Danyluk MD, Teplitski M. 2016. Development of an avirulent *Salmonella* surrogate for modeling pathogen behavior in pre- and postharvest environments. Applied and Environmental Microbiology 82:4100-4111. (Attachment 1)

de Moraes MH, Desai P, Porwollik S, Canals R, Perez DR, Chu W, McClelland M, Teplitski M. 2017. *Salmonella* persistence in tomatoes requires a distinct set of metabolic functions identified by transposon insertion sequencing. Applied and Environmental Microbiology 83:e03028-16. (Attachment 2)

de Moraes MH, Becerra-Soto E, Gonzáles IS, Desai P, Chu W, Porwollik S, McClelland M, Teplitski M. 2018. Genome-wide comparative functional analyses reveal adaptations of *Salmonella* sv. Newport to a plant colonization lifestyle. Frontiers in Microbiology 9:877. https://doi.org/10.3389/fmicb.2018.00877. (Attachment 3)

Fan, Y., Ginn, A., Ma, Z., Kang, M., Jeong, K.C. and Wright, A.C. (2017), Application of chitosan microparticles for mitigation of *Salmonella* in agricultural water. J Appl Microbiol, 123: 1346–1358. https://doi.org/10.1111/jam.13566

Teplitski M and de Moraes MH. 2018. Of mice and men....and plants: comparative genomics of the dual lifestyles of enteric pathogens. Trends in Microbiology (in press) https://doi.org/10.1016/j.tim.2018.02.008.

One of the published articles (de Moraes et al., 2017, AEM 83:e03028) was featured on the blog of the American Society for Microbiology in an article titled “How to be a successful foodborne pathogen: step 1, grow on food” (https://tinyurl.com/y93dgby2).

Project results will be disseminated at industry meetings and streamed through social media sources. Results also will be made available online as follows:

1. Final report to CPS is posted on the CPS website: https://www.centerforproducesafety.org/grant_opportunities_awards.php
2. CPS works with the scientists to publish results in scientific journals. Publication dates occur after the project is completed. Abstracts and awards can be found on the CPS website.
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The following websites provide additional resources on the final reports and symposium proceedings:

Center for Produce Safety: https://www.centerforproducesafety.org/resources.php
Produce Marketing Association: https://pma.com/topics/food-safety/center-for-produce-safety
Western Growers Association: https://www.wga.com/

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
64	Methods for detection of diverse parasites on packaged salads based on (viable) oocysts	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB15064	**Date Submitted:** December 2017
Recipient Contact: Bonnie Fernandez-Fenaroli	**Telephone:** (530) 554-9761	**Email:** bonnie@centerforproducesafety.org

Project Summary

Protozoan contamination of produce is of growing importance due to their current or projected capacity to cause significant illness in consumers of fresh produce. The prevalence of protozoa in developed countries, such as the United States, is likely to rise due to increasing demands for imported produce as well as climate change. However, fresh produce is rarely tested for protozoan pathogens. In addition, current methods used to detect protozoan (oo)cysts (the environmentally robust stage) require time-consuming techniques conducted by specialized laboratories. One critical issue that needs to be addressed for monitoring produce safety of packaged salads is to establish reliable methods for detection of protozoa in this food commodity. With a reliable protozoan detection toolset, future monitoring will become possible to perform risk assessment in the context of food safety. Thus, the motivation for this project stemmed from a lack of commercially available, user-friendly tests for protozoan pathogens in packaged salads.

The purpose of this study was to develop a novel test (multiplex polymerase chain reaction (PCR) assay) that can simultaneously detect and differentiate four protozoan pathogens in a rapid, accurate and affordable manner. The selected parasites—*Cryptosporidium* spp., *Giardia* spp., *Cyclospora cayetanensis* (*C. cayetanesis*) and *Toxoplasma gondii (T. gondii)*—were specifically targeted in this project due to their current and/or projected capacity to contaminate and cause illness in consumers of leafy greens. The detection limits of the newly developed assays were assessed in systematic laboratory spiking experiments by using spinach as a model leafy green vegetable. Additional tests with the capability to determine the viability of these parasites were optimized and applied for detection of viable protozoan parasites in leafy greens. Combined, the novel tool-set developed in the current study—using multiplex PCR for routine screening, followed by viability tests for further quantification of viable parasites—provides a fundamental advance for the produce industry to identify and manage health risks associated with parasite contamination of leafy green commodities.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

Development of simple one-step procedure for routine detection of the parasites: A new multiplex PCR assay for simultaneous detection of *Cryptosporidium* spp., *Giardia* spp., *T. gondii* and *C. cayetanensis* was developed. Several PCR assay conditions were evaluated for assay optimization. The specificity and sensitivity of the developed multiplex PCR assays were tested with the mixture of four protozoan parasites. The assay limits of detection (ALODs) in the parasite mixture were one (oo)cyst per reaction for *Cryptosporidium, Toxoplasma* and *Giardia*, and 10 oocysts per reaction for *Cyclospora*. ALODs appeared to be similar or lower (more sensitive) when each parasite was tested separately (Table 1 – see Attachment). The screening method was applied in subsequent spinach spiking experiments.

Optimization and adaptation of molecular methods for discrimination of live to dead parasites: In addition to developing a rapid and sensitive method for routine screening of protozoa, the performance of optimized and adapted viability tests was evaluated. Propidium monoazide (PMA), a photoreactive deoxyribonucleic acid (DNA)–binding dye, is used to detect viable microorganisms in molecular analysis. PMA treatment was optimized to discriminate live from dead *Giardia* in a molecular testing approach (quantitative polymerase chain reaction, qPCR) measuring DNA inside intact (oo)cysts. PMA treatment did not reliably discriminate live from dead *Cryptosporidium* and *Toxoplasma* due to their robust oocyst walls inhibiting PMA penetration, even after death. Another viability assay—reverse transcriptase quantitative polymerase chain reaction (RT-qPCR), which measures messenger ribonucleic acid (mRNA) expression from live cells—did successfully differentiate live from dead *Cryptosporidium* and *Toxoplasma* parasites. Therefore, selected viability assays were applied for the subsequent validation through systematic spinach spiking experiments and compared with microscopy methods (Table 2).

Spiking experiments for screening assays: The first set of spiking experiments was conducted, using spinach as a model leafy green vegetable, to evaluate the performance of the newly developed assays on salads spiked with the four target protozoan pathogens. To determine the efficiency of different treatment methods in recovering (oo)cysts from spinach, washing of spiked spinach with elution buffer by hand (wash experiment) was compared with the smasher instrument procedure (mash experiment). Serial dilutions of parasite mixtures ranging from 10 to 10,000 individual parasites were spiked onto spinach (10-gram portions) in three to five replicates. After recovery and concentration by centrifugation, protozoa (oo)cysts were analyzed using: 1) the newly developed multiplex PCR; 2) quantitative molecular methods specific for each parasite; and 3) previously established microscopy based techniques (Figure 1). The wash method provided equivalent or better amplifications of (oo)cysts as measured by multiplex PCR compared with the mash method (Table 3). *Cryptosporidium*, *Toxoplasma* and *Cyclospora* could be detected at a low concentration of 10 oocysts per 10 g of spinach by both methods, whereas *Giardia* amplified only as low as at 50 and 10,000 cysts per 10 g of spinach by the wash and mash techniques, respectively. The recovery of (oo)cysts as measured by microscopic and qPCR methods demonstrated lower recovery of *Giardia* with the mash method (Table 4) as compared with other pathogens. Using the presence/absence detection data from the spinach spiking experiments, logistic regression was applied to create a probability curve for estimating the likelihood of parasite detection under a range of theoretical contamination levels expressed as (oo)cysts per 10 g of spinach. Modeling results suggest that washing spinach leaves yielded better recovery and therefore more sensitive detection of parasites as compared with the mash approach. Using *Toxoplasma* as an example, oocysts could be accurately detected 90% of the time at contamination levels of 10 or 100 oocysts per 10 g spinach, using the wash or the mash technique, respectively (Figure 2). When the hand-wash technique was applied, successful detection of parasites would occur at 90% likelihood when contamination levels on 10 g of spinach were 10, 35, 45, and 55 (oo)cysts for *Toxoplasma*, *Cryptosporidium*, *Giardia*, and *Cyclospora*, respectively (Figure 3).

Spiking experiments for viability assays: The second set of spiking experiments was performed to assess the limits of detection of selected viability assays and their ability to discriminate live from dead (oo)cysts on spinach. In the first experiment, serial dilutions of live *Cryptosporidium*, *Giardia*, *Toxoplasma* and *Cyclospora* mixtures were prepared to obtain concentrations ranging from 10 to 1000 (oo)cysts and spiked on spinach in five replicates (Figure 4). RT-qPCR results showed that mRNAs were detected on spinach spiked with as low as 10 *Cryptosporidium* and *Giardia* and 50 *Toxoplasma* (oo)cysts (Figure 5). No targeted mRNA was detected on spinach spiked with phosphate buffered saline (PBS) as a negative control (data not shown).

Logistic regression of RT-qPCR results indicated that the assays would yield positive detection of parasites 90% of the time when 16, 21 and 93 (oo)cysts of *Cryptosporidium*, *Toxoplasma* and *Giardia* per 10 g of spinach were present, respectively (Figure 6). Molecular tests combined with PMA treatment were also conducted but *Giardia* were only detected in a portion of replicates spiked at the highest concentration of 1,000 cysts (data not shown).

In the second experiment, spinach was spiked with mixtures of live and dead parasites to evaluate the effect of different proportions of live (oo)cysts in protozoan contamination, which simulates more realistic environmental conditions. Live and dead parasites were mixed in defined ratios of 5,000 total (oo)cysts and spiked on spinach in five replicates (Figure 4). The increasing proportions of dead protozoa spiked on spinach may have inhibited the mRNA amplification from live *Cryptosporidium* and *Giardia* but not from *Toxoplasma* (Figure 7). This result suggested that the detection of live *Cryptosporidium* and *Giardia* may be underestimated when dead (oo)cysts are present in large concentrations on contaminated salads. The probability of detecting viable *Giardia* on spinach was calculated using RT-qPCR and PMA-qPCR/PCR (Figure 8). The results suggested that detection with higher sensitivity would occur using PMA-PCR or RT-qPCR analysis (220 and 110 cysts per 10 g of spinach, respectively) compared with PMA-qPCR. The total costs of PMA-PCR and RT-qPCR analyses in this study were estimated at $17 and $25 per sample, respectively (including the cost for DNA/RNA extraction and for analytical duplicate plus nested PCR reaction in PMA-PCR or for analytical duplicate plus two dilutions in RT-qPCR). Although PMA-PCR may provide relatively lower sensitivity than RT-qPCR, the PMA-PCR assay for the detection of live *Giardia* would be useful, especially when a simpler and more affordable method is preferred in viable *Giardia* monitoring. Microscopic-based viability staining results suggested that discriminating dead from live *Giardia* cysts spiked on spinach was not as clearly visualized as when parasites were suspended in phosphate buffered saline (data not shown); thus, this approach may not be as efficient for *Giardia* viability determination on leafy greens as compared with RT-qPCR or PMA-PCR.

In June 2017, the principal investigator (PI) presented final research results at the Center for Produce Safety (CPS) Research Symposium in Denver, Colorado.

This project focused solely on detection of pathogens known to be of concern with fresh produce, and does not enhance the competitiveness of non-specialty crops.

The project partners for this project were the CPS and the University of California, Davis. CPS managed the project and the University of California, Davis performed the research studies.

Goals and Outcomes Achieved

Two key challenges to the produce (and produce-packing) industry were addressed in the current investigation: 1) development of a rapid, accurate, and affordable test (by molecular means) for simultaneous detection of four selected protozoan parasites in leafy greens; and 2) optimization and validation of viability assays that discriminate live from dead parasites on produce. A newly developed qualitative nested multiplex-PCR assay was sensitive (1–10 parasites per reaction) for detection of low levels of parasites and accurately detected 10–50 parasites spiked on 10 grams of spinach as determined in spiking experiments. The ALODs in the parasite mixture were determined to be one (oo)cyst per reaction for *Cryptosporidium*, *Toxoplasma* and *Giardia*, and 10 oocysts per reaction for *Cyclospora*. For viability assays, RT-qPCR was compared with PMA coupled with real-time as well as conventional PCR assays (qPCR/PCR). The RT-qPCR assays could

accurately detect 20 (*Cryptosporidium* and *Toxoplasma*) and 90 (*Giardia*) (oo)cysts spiked on 10 grams of spinach. However, the research team did note that the presence of large numbers of dead parasites on spiked spinach may result in underestimation of live *Cryptosporidium* and *Giardia* (oo)cyst quantification by RT-qPCR. PMA-PCR effectively discriminated live from dead *Giardia* at contamination levels of 220 cysts on 10 grams of spinach using a relatively simple and affordable approach.

Outcome measures for this project were not long term.

Goal 1 was to develop a multiplex PCR assay. This assay was developed within the grant period.

Goal 2 was to optimize viability assays for *Cryptosporidium, Giardia, Toxoplasma* and *Cyclospora.* Viability assays were optimized for all parasites with the exception of *Cyclospora.* Although the team had a working collaboration with experts at the U.S. Centers for Disease Control (CDC), adequate samples yielding viable *Cyclospora* oocysts were not submitted within the study duration. Thus, only screening assays (Goal 1) based on parasite DNA (viable or not) were developed for this parasite (*Cyclospora*).

Goal 3 was to validate the use of screening and viability assays on leafy greens. A set of systematic spiking experiments was conducted, demonstrating the feasibility of applying the newly developed assays as well as optimized viability assays on spinach, as a model leafy green vegetable.

Key baseline data that have been gathered include: 1) detection limits for four selected protozoan parasites in leafy greens (e.g., on 10-g spinach samples) using the newly developed multiplex PCR assay; 2) recoveries of protozoan oocysts spiked on spinach samples as measured by qPCR; 3) probability of detecting target protozoa spiked on spinach in spiking experiments (wash and mash techniques); and 4) probability of detecting three viable target protozoan parasites via RT-qPCR assays that discriminate live from dead parasites on produce. The outcomes achieved were discussed in the previous section; additionally, see Attachment for tables and figures.

The project had several successful outcomes, as follows:
A key outcome of this project was the development of a new molecular test that can simultaneously detect and differentiate the presence of four important foodborne parasites on produce. This assay, a multiplexed, nested conventional PCR test, is simple, rapid (<24 h), and inexpensive. Systematic spiking experiments demonstrated the ease of application of this test on leafy greens, using spinach as a model produce salad. The low detection levels of the assay demonstrate applicability of the method for efficient screening of food commodities. The multiplex-PCR assay was sensitive (1–10 parasites per reaction) for detection of low levels of parasites and accurately detected 10–50 parasites spiked on 10 g of spinach as determined in spiking experiments. The ALODs in the parasite mixture were 1 (oo)cyst per reaction for *Cryptosporidium*, *Toxoplasma* and *Giardia*, and 10 oocysts per reaction for *Cyclospora*.

The optimization and validation of several viability assays for discriminating live from dead parasites on produce presents a fundamental advance in the field of produce safety. Detection of parasite DNA alone is not sufficient for making appropriate management and/or policy decisions that affect public health. Insight on whether positive detection via screening tests is due to the presence of infectious pathogens (as opposed to nonviable organisms) is imperative. Project results demonstrate that RT-qPCR can effectively discriminate viable from dead *Toxoplasma, Cryptosporidium* and *Giardia* on spinach; the PMA-PCR assay for the

detection of live *Giardia* would be useful when a simpler and more affordable method is preferred. For viability assays, the RT-qPCR assays could accurately detect 20 (*Cryptosporidium* and *Toxoplasma*) and 90 (*Giardia*) (oo)cysts spiked on 10 g of spinach. However, the research team did note that the presence of large numbers of dead parasites on spiked spinach may result in underestimation of live *Cryptosporidium* and *Giardia* (oo)cyst quantification by RT-qPCR. PMA-PCR effectively discriminated live from dead Giardia at contamination levels of 220 cysts on 10 g of spinach using a relatively simple and affordable approach.

Currently available commercial methods for protozoan pathogen detection on environmental matrices are laborious, expensive, and require specific personnel training in microscopy (as per Environmental Protection Agency method 1623 for *Cryptosporidium* and *Giardia*) or are completely lacking (for *Toxoplasma* and *Cyclospora*). In comparison, both the screening multiplex PCR and RT-qPCR as well as PMA-PCR methods used for viability discrimination can be adopted for immediate use by any laboratory with molecular testing capacity.

The application of user-friendly and cost effective tests for routine monitoring of produce for parasite contamination will yield field surveillance data essential for investigations aimed at predicting risks of illness to consumers via quantitative microbial risk assessment.

Beneficiaries

The user-friendly multiplex PCR test developed in the project can be readily used for routine screening of protozoan (oo)cysts on produce. This project's accomplishments will provide a toolset to recognize protozoan pathogen contamination on produce allowing the implementation of prevention strategies. Improved detection of these parasites by molecular methods that are fast, specific, and have acceptably low detection limits fills a big gap to improve monitoring strategies and provides data to develop quantitative microbial risk assessment scenarios. The beneficiaries are the relevant growers, harvesters and processors of leafy greens. The ability to certify the absence of certain pathogens will guide more specific and effective risk management practices for the industry and provide new insights into optimization of processes.

This project will, at minimum, benefit the more than 90 member companies of the California Leafy Green Products Handler Marketing Agreement that work with hundreds of farmers in the state to produce and handle lettuce, spinach and other leafy greens products. According to the California Agricultural Statistics Review 2015–2016, the lettuce production alone is valued at $2.2 billion annually. Additionally, since the toolset is not limited to leafy greens and can be optimized for other produce types, it is reasonable to expect that the total number of potential beneficiaries could extend to growers, harvesters and processors of other specialty crops, such as berries and cilantro, which can suffer from common protozoan contamination. According to the 2012 Census of Agriculture there are 1,985 berry growers farming over 52,000 acres in California.

The PI at the University of California, Davis presented final research results in June 2017 at the 8th annual CPS Research Symposium in Denver, CO, to 325 symposium attendees. Interim results were presented previously in an oral presentation at the 2016 CPS Research Symposium in Seattle, WA (315 attendees), and in a poster session at the 2015 CPS Research Symposium in Atlanta, GA (245 attendees). The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to comment on the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Project results will be disseminated at industry meetings, and streamed through social media sources. Results also will be made available online as follows:

1. Final reports submitted to CPS (after the June 2017 symposium) are posted on the CPS website: http://www.centerforproducesafety.org/grant_opportunities_awards.php.
2. CPS works with the scientists to publish results in scientific journals. Publication dates occur after the project is completed. Abstracts and awards can be found on the CPS website.
3. The Board of Directors and members of the Technical Committee of CPS distribute a series of information briefs throughout the year on the website and through presentations, meetings and webinars. An example of this would be the "CPS 2016 Research Symposium Key Learnings" on the CPS website at the following link: http://www.centerforproducesafety.org/amass/documents/document/365/CPS%202016%20Key%20Learnings.pdf.

The following websites provide additional resources on the final reports and symposium proceedings:
Center for Produce Safety: http://www.centerforproducesafety.org/resources.php
Produce Marketing Association: http://pma.com
Western Growers Association: http://www.wga.com/

Lessons Learned

Positive results are that the novel multiplex PCR test can be immediately adopted for long-term use by the produce industry for screening leafy greens for the presence of parasites. Also, the multiplex PCR test can be optimized for application to other produce commodities, such as berries, that are at risk for contamination with parasites. The team's results indicate that applying viability assays in field surveillance investigations would be the key to minimizing contamination due to live versus dead parasites, and will aid accurate modeling efforts to predict the risk of illness to consumers.

There were no unexpected outcomes or results for this project.

Addressing food safety concerns due to viable *Cyclospora cayetanensis* contamination is especially challenging due to the difficulty in obtaining oocysts for research purposes. Unlike the other three protozoan parasites targeted in this study, *Cyclospora* is a human-specific pathogen and its oocysts can only be obtained from diarrheic stool samples of patients. While the research team succeeded in procuring oocysts for development of a screening assay, the viability state of the parasites could not be verified by the project collaborator at the CDC. A collaborative framework among produce industry partners, academic institutions, state-level public health laboratories, and the CDC is strongly recommended for strategizing surveillance and sample collection approaches that would maximize resources for advancing research on this important emerging infectious disease agent.

Additional Information

See Attachment for Tables 1–4 and Figures 1–8.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 65	**Project Title:** Validating a Physically Heat-Treated Process for Poultry Litter in Industry Settings using the Avirulent *Salmonella* Surrogates or Indicator Microorganisms	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB15065	**Date Submitted:** December 2018
Recipient Contact: Bonnie Fernandez-Fenaroli	**Telephone:** (530) 554-9761	**Email:** bonnie@centerforproducesafety.org

Project Summary

Poultry litter, which is a waste by-product of poultry production, is rich in nutrients and has a great value as a soil amendment and organic fertilizer for produce production. Poultry litter also is known to contain human pathogens such as *Salmonella* spp. Therefore, direct application of this waste material to agricultural land can be risky to the environment and food supply. Currently, both composting and physical heat-treatment processes are considered effective for pathogen inactivation in poultry litter. However, studies have shown that some enteric pathogens can adapt to sublethal temperature or desiccation conditions during stockpiling on the farms, and develop resistance to further heat treatments. The team's previous project funded by the 2011 Specialty Crop Block Grant Program (SCBGP) Project 67: *Validating Salmonella Inactivation During Thermal Processing of the Physical Heat-Treated Chicken Litter as Soil Amendment and Organic Fertilizer* identified various factors that can significantly affect the inactivation rate of *Salmonella* in chicken litter, including the physiological stage of *Salmonella*, moisture level of chicken litter, heating source (wet vs. dry heat), and heat treatment temperature. A typical litter processing plant employs a large natural gas–fired rotary dryer (~15 meters in length), with an inlet temperature of 121°C or higher and an exit temperature of 70–80°C, which can produce more than 100 tons per day of poultry litter along with different formulations of biological soil amendments. During the heating process, the rapid loss of moisture from poultry litter may result in the development of thermal resistance by microorganisms. Although physically heat-treated chicken litter has been recommended and used by produce growers, there is a lack of scientific data to prove that the heating processes, in terms of time-temperature combinations in commercial processing plants, are adequate to kill *Salmonella*. To perform the process validation for physically heat-treated poultry litter in industry settings, an avirulent surrogate or indicator microorganism for *Salmonella* is essential due to biosafety concerns. Although studies have reported using strains of avirulent *Salmonella* or enterococci for food processing, produce contamination, or composting-related research, no study had been conducted on identifying a *Salmonella* surrogate or indicator microorganisms to use in processing physically heat-treated poultry litter. Therefore, this project compared the thermal resistance of *Salmonella* with selected indicator and surrogate microorganisms and then used these microorganisms to validate the thermal processing of poultry litter in three commercial plants.

To reduce foodborne illnesses associated with fresh produce, interventions to control contamination at the farm level are critical. The newly implemented United States (U.S.) Food and Drug Administration Food Safety Modernization Act (FSMA) rule on establishing science-based minimum standards for the safe production and harvesting of fruits and vegetables has recommended the use of scientifically valid controlled processes for biological soil amendments of animal origin. Clearly, both fertilizer and produce industries are facing the challenges on how to produce and apply biological soil amendments to agricultural land safely. Therefore, this project on validating *Salmonella* inactivation during thermal processing of the physically heat-treated poultry litter is urgently needed to provide some practical guidelines on time-temperature

combinations to treat poultry litter with different properties in order to produce finished products that are *Salmonella*-free.

The team's previously funded 2011 SCBGP Project 67 determined the thermal resistance of *Salmonella* in chicken litter as affected by temperature, time, moisture, types and freshness of chicken litter, and physiological stage of the microorganism. In addition, a two-step treatment was developed for rapid inactivation of *Salmonella*, consisting of a moist-heat treatment at 65°C for one hour and a sequential dry-heat treatment at 85°C for one hour. The previous study was conducted on a small scale under controlled laboratory conditions. The current project built on those previous laboratory-based research findings to provide further validation of the process in industry settings to provide recommendations for the organic fertilizer industry on proper heat treatments to produce the finished products free from pathogenic microorganisms.

Project Approach

First, the team evaluated a suitable surrogate and indicator microorganisms for *Salmonella* by determining the thermal resistance in physically heat-treated poultry litter at high temperatures (Objective 1). Briefly, aged broiler litter or turkey litter compost with 20, 30, 40, and 50 percent moisture content was inoculated with desiccation-adapted *Salmonella* Senftenberg (~10^7 log cfu/g) or desiccation-adapted *Enterococcus faecium* NRRL B-2354 (as a surrogate for *Salmonella*), and then heat treated at 75, 85, or 150°C for three hours. The surviving populations of *S.* Senftenberg, *E. faecium* NRRL B-2354, indigenous enterococci, and total aerobic bacteria were enumerated. Linear regression analysis was performed to calculate the correlations between the mean log reductions of desiccation-adapted *S.* Senftenberg and *E. faecium* NRRL B-2354, indigenous enterococci or total aerobic bacteria in compost samples. The results clearly demonstrated that both *E. faecium* NRRL B-2354 and indigenous enterococci are more heat resistant than *Salmonella,* and therefore provide a sufficient safety margin for validation of the heat processing of poultry litter. Overall, the data generated from modeling clearly revealed that microbial cells were inactivated more rapidly when the temperature and moisture content of poultry litter were increased. Based on thermal inactivation data, the team concluded that 1.2–2.7 log or more reductions of *E. faecium* NRRL B-2354 may predict >5-log reductions of *Salmonella* in poultry litter, depending on heating temperature, moisture content, and type of poultry litter (Attachment 1 - Table 1).

To validate the thermal processes in commercial plants (Objective 2), a multiple-component sampler that is resistant to the high temperatures and strong physical forces inside industrial dryers was designed, custom made, and tested in two processing plants (plants A and B). To determine the residence time of the dryer, color-coded magnetically retrievable MicroTracers (Micro-Tracers, Inc.) were tested in plant A, in triplicate runs. A total of seven pilot trials for thermal process validation were conducted in three industrial collaborators' plants throughout the project. Briefly, fresh, partially composted samples were requested from each processor, and these were inoculated with *E. faecium* NRRL B-2354 and then shipped overnight at room temperature to the processing plants, allowing bacterial cells to become desiccation-adapted in the litter. On the following day, the customized samplers containing the inoculated samples were dropped into the entry of the industrial dryer in each plant (A and B); the samplers collected at the exit of the dryer were packed with cold packs and sent overnight to the lab for analysis of the surviving populations of surrogate and indicator microorganisms. Due to the business shutdown of processing plant B, another plant (C) was recruited for additional validation trials. Since plant C is a small batch operation, the entire batch was inoculated with the desiccation-adapted *E. faecium* NRRL B-2354, and the treated samples were collected and analyzed in the lab

following overnight shipment. For each trial, duplicate runs for each treatment (litter at two moisture levels for plants A and B, and one level for plant C) were conducted.

The thermal processes in all three plants achieved reductions of 2.93–7.45, 1.72–3.74, and 1.49–2.61 log CFU/g for *E. faecium* NRRL B-2354, presumptive indigenous enterococci, and total aerobic bacteria, respectively (Attachment 1 Table 2). Reductions were dependent on the compost type, moisture level, dryer type, and seasonality. For plant A, both seasonality and moisture content of turkey litter compost prior to the dryer had no significant effect on the reduction of *E. faecium* NRRL B-2354 but did have a significant effect ($P < 0.05$) on the reduction of presumptive indigenous enterococci, likely due to the variation of presumptive indigenous enterococci species in compost from trial to trial. Based on the data obtained from Objective 1 experiments, the validation trials using *E. faecium* as a surrogate and indigenous presumptive enterococci as indicator microorganisms for *Salmonella* demonstrated that the processing conditions in all plants were adequate to reduce *Salmonella* levels by at least 5 log, even though the processing conditions varied among trials.

For Objective 2, the team also compared selective media for enumerating indigenous enterococci from composts, and analyzed the indigenous microbial community in poultry litter samples as affected by thermal processing by selective plating, denaturing gradient gel electrophoresis, and metagenomic sequencing. Results demonstrated that enterococcosel agar was better than bile esculin agar for enumeration of presumptive indigenous enterococci from poultry litter samples due to less growth of interfering species; however, some bacterial species other than enterococci could grow on enterococcal selective agar plates. Analysis of the microbial community revealed that profiles varied significantly among different types of poultry litter, and the thermal process reduced 95 to 99.9 percent of total aerobic bacterial populations in the poultry litter/composts. Based on metagenomic sequencing analysis, the most abundant communities (i.e., Bacillaceae) were decreased and species evenness became more distinct in the turkey litter after heat treatment, indicating that heat treatment had different effects on the microbial community. Results generated from this study of processing plant validation will help poultry litter processors to modify their existing process parameters to produce microbiologically safe organic fertilizers and soil amendments, thereby reducing a possible source of produce contamination on farms.

In June 2017 the Principal Investigator (PI) presented interim results of the project at the Center for Produce Safety (CPS) Research Symposium in Denver, Colorado, to 325 attendees.

This project did not enhance the competitiveness of non-specialty crops.

The project partners are CPS, Clemson University, and three commercial poultry litter processors where process validation studies were carried out. CPS managed the project and Clemson University performed the research. The poultry litter processors provided access to their facilities for validation trials to be carried out.

Goals and Outcomes Achieved

Completed activities included (i) selection of an avirulent *Salmonella* surrogate (*Enterococcus faecium* NRRL B-2354) and indicator microorganisms (presumptive indigenous enterococci) that are suitable for process validation of a physical heat-treatment for poultry litter, and (ii) validation of the thermal processes used in three industrial settings (poultry litter processing plants) using the *Salmonella* surrogate and indicator

microorganisms, to achieve >5-log reductions of *Salmonella*, to ensure the production of *Salmonella*-free physically heat-treated poultry litter.

One long-term outcome measure was the publication of research findings. To date, the findings have been reported and published in five peer-reviewed papers in food safety–related scientific journals, and one paper is currently in submission (see Additional Information). One of these papers (Chen and Jiang, 2017, J Food Protection 80:392–405) is a review paper that can be considered as extension and outreach for this project. Presentation of interim research findings was made at the annual CPS Research Symposium in 2015–2017 and at the annual meeting of the International Association for Food Protection in 2016–2017. Final research findings were presented in 2018 at both meetings. Presentations were not made at other meetings (as originally planned) since there was no budget to attend those meetings (i.e., Annual Southeast Vegetable & Fruit Expo, and the National Association of County Agricultural Agents Annual Meeting and Professional Improvement Conference).

The original goals of this project were to provide the tools (i.e., surrogate and/or indicator microorganisms for *Salmonella*) and guidelines (i.e., time and temperature combinations, and moisture level) for the poultry litter processing industry to produce microbiologically safe biological soil amendments, as well as to validate the heat-treatment processes in industrial facilities. These tools, guidelines, and validations were accomplished. In addition, the project identified indigenous microbial species in poultry litter that survived the physical heat treatment, which may lead to future studies on biological control of pathogens in soil amendments.

The goal of selecting an avirulent surrogate and indicator microorganism for *Salmonella* that is suitable for process validation of a heat treatment for poultry litter has been met, and the surrogate was used for seven plant trials carried out in three industrial collaborators' plants. The project results have clearly demonstrated that it is feasible to develop a validation strategy to monitor the effectiveness of thermal processes for poultry litter, without introducing pathogens into the industrial environment. The thermal inactivation data collected indicated that reductions in the surrogate *E. faecium* NRRL B-2354 of 1.2–2.7 log or more may be used to predict >5-log reductions of *Salmonella* in poultry litter, depending on heating temperature, moisture content, and poultry litter type. (see Attachment 1 for Table 1 and 2 data.)

The project identified *E. faecium* NRRL B-2354 as a suitable *Salmonella* surrogate and presumptive indigenous enterococci as indicator microorganisms for poultry litter processing plant validation studies. The team used *E. faecium* NRRL B-2354 and presumptive indigenous enterococci to successfully validate the thermal processes of three poultry litter plants under different seasons. Based on the thermal inactivation data, 1.2–2.7-log reductions of *E. faecium* NRRL B-2354 may predict >5-log reductions of *Salmonella* in poultry litter, depending on heating temperature, moisture content, and poultry litter type, which will provide a sufficient safety margin for the heat processing of poultry litter. The multiple-component sampler basket that was custom-designed in this project is capable of withstanding the harsh environment (high temperature, strong physical forces) inside the industrial dryers, and provided a carrier for the inoculated poultry litter samples to be exposed to the actual thermal process within the dryers. The microbiological analysis of samples from the seven plant trials validated the current processing conditions (e.g., drying temperature/time, normal range of moisture levels in incoming raw litter) employed by the three industrial partners as adequate to achieve >5-log reduction of *Salmonella* in the finished products of physically heat-treated poultry litter. Also, the multiple-component sampler was successfully used to measure residence time of samples within the dryer more accurately than using magnetically retrievable MicroTracers. The metagenomic sequencing

analysis revealed that the most abundant communities (i.e., Bacillaceae) decreased significantly and species evenness became more distinct in the turkey litter compost after heat treatment, indicating that heat treatment had different effects on the microbial community. In summary, both the indicator and surrogate microorganisms, along with the custom-designed sampler, can be practical tools for poultry litter processors to routinely monitor or validate their thermal processes without introducing pathogens into the industrial environment. Based on the ease-of-use and low cost to enumerate indigenous enterococci, poultry litter processors could do routine monitoring of their thermal process by using indicator microorganisms if minor changes occur to their processing parameters. However, for a validation study, the inoculation of litter with *E. faecium* NRRL B-2354 is preferable due to the fluctuation of indigenous enterococci populations in animal waste–based soil amendments. Overall, the findings from this study will assist poultry litter processors in optimizing their existing process parameters to produce *Salmonella*-free physically heat-treated poultry litter, which can be used by the produce industry to grow microbiologically safe products.

Beneficiaries

Biological soil amendment processors or compost suppliers, and fresh produce growers are the primary beneficiaries of this research. The processors of physically heat-treated chicken litter or compost processors can utilize the research findings to identify the critical factors (such as freshness and moisture level of raw poultry litter, physiological stages of pathogen, time and temperature of the physical heat treatment) affecting *Salmonella* survival during thermal processing, and set up the criteria for rapidly destroying the pathogen in the finished products. Specialty crop farmers will be able to obtain *Salmonella*-free soil amendments or organic fertilizers for growing fresh specialty crop produce, and thereby reduce cross contamination of fresh produce via soil amendment. The ultimate beneficiary will be the U.S. public who will get safe, fresh produce to consume, and will have increased confidence in consuming fresh specialty crop produce without fear of foodborne illnesses.

This study will directly impact the specialty crop produce industry and the compost industry in California and nationwide as well as consumers of these products. Water, soil, and compost are three of the major inputs in the production of fresh specialty crop produce. As California produces nearly half of U.S.-grown fruits, nuts and vegetables, it is imperative that California's produce industry can verify the absence of human pathogens, including *Salmonella*, in these inputs that are used to produce their crops. The U.S. Department of Agriculture estimated U.S. poultry inventory in 2016 at 8.78 billion broilers (raised for meat), 1.64 billion layers producing 102 billion eggs, and 244 million turkeys, with about 550 million tons of manure each year (https://www.nass.usda.gov). According to the U.S. Composting Council (http://compostingcouncil.org/), there are >1,000 licensed compost producers in the nation. Of these, there are nearly 170 businesses in California that produce compost and mulch (http://www.calrecycle.ca.gov/organics/Processors/). According to the U.S. Department of Agriculture, Economic Research Service, nearly 4,438 produce farms (total number of produce acres: 549,437) covered by the FSMA proposed rule in the U.S. in 2013 have reported using biological soil amendments of animal origin (specifically manure); it was estimated that 81.5 percent of the total number of organic produce farms using animal manure were using treated animal manure. The research team has worked closely with composting and fertilizer industries through SCBGP-funded projects. The industrial collaborators involved in these studies are very interested in the microbiological safety of their animal waste–based compost products. The research findings from this study will provide the tools and procedures for the composting industry to validate or monitor their physical heat-treatment process to produce pathogen-free poultry litter, which will benefit the specialty crop produce industry to grow safe products for human consumption using microbiologically safe biological soil amendments.

The PI from Clemson University presented final research results in June 2018 at the 9th annual CPS Research Symposium in Charlotte, North Carolina, to 300 symposium attendees. Interim results were presented previously in an oral presentation at the 2017 CPS Research Symposium in Denver, Colorado (325 attendees), and in a poster session at the 2016 CPS Research Symposium in Seattle, Washington (315 attendees). The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to discuss the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Project results were disseminated at industry meetings and streamed through social media sources. Results were also made available online as follows:

1. Final report to CPS is posted on the CPS website: https://www.centerforproducesafety.org/grant_opportunities_awards.php
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The following websites provide additional resources on the final reports and symposium proceedings:
Center for Produce Safety: https://www.centerforproducesafety.org/resources.php
Produce Marketing Association: https://pma.com/topics/food-safety/center-for-produce-safety
Western Growers Association: https://www.wga.com/

Lessons Learned

As the team's research is applied science, any research findings will have a direct impact on practices and performance in the biological soil amendment industry. In-depth communication with the industry has been essential for the team to better understand their process, products, and needs, and to help the experimental design. The second objective of this project was to conduct validation trials in commercial processing plants. Since commercial production is the top priority of the industrial partners, the team ensured that scheduling the plant trials complied with the plant's production schedules and personnel availability. The most important lessons learned were to get industry excited about the project and actively involved, and then design the research to answer the industry needs.

Due to the business shutdown of one industry collaborator, halfway through the plant trials, the team had to recruit another poultry litter processing plant in a short period of time. Fortunately, a member of the CPS Board of Directors helped the team connect with a replacement processing plant, who graciously allowed the team to coordinate plant trials in a fertilizer (laying hen litter) plant.

All project goals were achieved.

Additional Information

Publications:

1. Chen, Z., and X. Jiang. 2017. Microbiological safety of animal wastes processed by physical heat treatment: an alternative to eliminate human pathogens in biological soil amendments as recommended by the Food Safety Modernization Act. J. Food Prot. 80:392-405.
2. Chen, Z., and X. Jiang. 2017. Selection of indigenous indicator microorganisms for validating desiccation-adapted *Salmonella* reduction in physically heat-treated poultry litter. J. Appl. Microbiol. 122(6):1558-1569. doi: 10.1111/jam.13464
3. Chen, Z. and X. Jiang. 2017. Thermal resistance and gene expression of both desiccation-adapted and rehydrated *Salmonella enterica* Typhimurium in aged broiler litter. Appl. Environ. Microbiol. 83(12):e00367-17. doi: 10.1128/AEM.00367-17
4. Wang, H., M. Dharmasena, Z. Chen, and X. Jiang. 2017. Persistence of non-O157 Shiga toxin-producing *Escherichia coli* in dairy compost during storage. J. Food Prot. 12:1999-2005. doi: 10.4315/0362-028X.JFP-16-552
5. Chen, Z., J. Kim, and X. Jiang. 2018. Survival of *Escherichia coli* O157:H7 and *Salmonella enterica* in animal waste-based composts as influenced by compost type, storage condition and inoculum level. J. Appl. Microbiol. 124:1311-1323. doi: 10.1111/jam.13719
6. Wang, H., Z. Chen, M. Li., X. Jiang, and J. Wang. Selection of surrogate microorganism for validating desiccation-adapted *Salmonella* reduction in physically heat-treated broiler litter. J. Food Prot. (in submission)

Presentations:

1. Jiang, X. and A. Greene. 2016. Validating a physically heat-treated process for poultry litter in industry settings using the avirulent *Salmonella* surrogates or indicator microorganisms. 7th Annual CPS Research Symposium, June 28-29, Seattle, WA.
2. Wang, H., Z. Chen, C. Gong and X. Jiang. 2016. Thermal inactivation of avian virus surrogates in aged chicken litter. International Association for Food Protection (IAFP) Annual Meeting, St. Louis, MO.
3. Chen, Z. and X. Jiang. 2016. Selection of indigenous indicator microorganisms for validation of desiccation-adapted *Salmonella* reduction in physically heat-treated poultry litter. IAFP Annual Meeting, St. Louis, MO.
4. Jiang, X. and A. Greene. 2017. Validating a physically heat-treated process for poultry litter in industry settings using the avirulent *Salmonella* surrogates or indicator microorganisms. 8th Annual CPS Research Symposium, June 20-21, Denver, CO.
5. Wang, H., Z. Chen, and X. Jiang. 2017. Optimizing methods for recovering heat-injured *Enterococcus faecium* and indigenous enterococci in turkey litter compost. IAFP Annual Meeting, Tampa, FL, 7/9-12.
6. Wang, H., Z. Chen, M. Dharmasena, M. Li, A. Greene, B.M. Gardener, B. Holden, J. Wang and X. Jiang. 2018. Thermal inactivation of *Salmonella* surrogate and indicator microorganisms in turkey litter compost during physical heat-treatment process - A plant validation study. IAFP Annual Meeting, Salt Lake City, UT, 7/8-11 Abstract T9-10.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 66	**Project Title:** Pathogen physiological state has a greater effect on outcomes of challenge and validation studies than strain diversity	
Grant Recipient: The Center for Produce Safety	**Grant Agreement No.:** SCB15066	**Date Submitted:** December 2018
Recipient Contact: Bonnie Fernandez-Fenaroli	**Telephone:** (530) 554-9761	**Email:** bonnie@centerforproducesafety.org

Project Summary

Effective control of foodborne pathogens on produce and in produce-associated environments requires science-based validation of interventions and control strategies. Typically, multiple strains are used for most microbial challenge studies in which strains are grown under conditions that most likely provide the greatest resistance to a given challenge. This approach accounts for strain diversity by including multiple distinct strains, serotypes, subtypes, and specific food-associated strains. However, it has been well documented for key pathogens of concern that pathogen strains differ in their ability to survive stress conditions. Also, pre-growth conditions have a considerable effect on pathogen growth and survival under subsequent stresses and increase the range of physiological responses of pathogens in challenge and validation studies. This project addresses the need for science-based challenge and validation studies by providing a comprehensive data set that allows the produce industry to justify use of (i) specific pre-growth conditions and (ii) specific pathogens, surrogate, indicator, and index strains. The key goal of this project was to determine whether strain diversity or different pre-growth conditions yield a larger variation in response to different intervention and control strategies, and which strains and types of conditions may yield the largest differences in response. These data will allow industry to perform more informed challenge studies and to make rational decisions on strain cocktails and growth conditions used prior to challenge studies. This information will be particularly valuable considering the changing food safety regulatory environment (including the Food Safety Modernization Act), which places an increasing emphasis on science-based approaches and scientific validation of preventive controls. As an essential part of this project, a produce-relevant strain collection was developed, which includes *Salmonella*, *Listeria monocytogenes*, and Shiga toxin–producing *E. coli* (STEC), as well as surrogate, indicator, and index strains, and this collection was made available to industry, government agencies, and other stakeholders.

Studies evaluating pathogen interventions as well as growth and survival of pathogens in produce are essential for the development of scientifically valid control strategies and preventive controls as well as for accurate and industry-relevant risk assessments. In addition, standardization of strains and growth conditions used in validation and challenge studies need to allow for better comparison between studies, which will facilitate easier and more rapid decision making on the use of interventions and control strategies. To address these challenges, a produce-relevant standard strain collection with a total of 55 strains was developed, including (i) 23 *Salmonella enterica*, (ii) 11 *Listeria monocytogenes*, (iii) 13 Shiga toxin–producing *E. coli* (STEC), and (iv) eight surrogate, indicator, and index organisms. This collection is publicly available, and all strains have been validated through whole genome sequencing. An extensive number of experiments were conducted to evaluate the growth and survival of selected strains when pre-grown under seven different conditions (e.g., high salt, low pH, low water activity) followed by (i) exposure to sanitizer, and (ii) inoculation on fresh produce items (i.e., tomato, cantaloupe rind, pre-cut romaine lettuce). The data generated indicate that pre-growth conditions have a greater effect on pathogen survival in challenge and validation studies than strain diversity. This information and the strain collection developed are particularly timely and important as

industry faces increasing pressure to develop scientifically validated interventions. In addition, increased standardization of strains and growth conditions used in validation and challenge studies is also needed to allow for better comparison between studies. The importance and timeliness of this study is also supported by the changing food safety regulatory environment, which places an increasing emphasis on science-based approaches and scientific validation of control strategies and interventions; scientifically justifiable strain selection and growth conditions for validation and challenge studies are an essential part of a science-based food safety system.

This project is built upon, to a limited extent, the 2012 Specialty Crop Block Grant Program (SCBGP) Project 65: *Genomic Elucidation of the Physiological State of Enteric Pathogens on Pre-Harvest Lettuce*. This project did not duplicate or continue the previous project, which focused on evaluating the physiology of *Salmonella* and STEC on preharvest lettuce. However, the previous SCBGP project provided initial support of considerable strain differences with regards to survival of chlorine treatment among different STEC strains, which was one of the observations that led to the development of this project.

Project Approach

This project entailed four specific objectives.

Objective 1 was to assemble a collection of *Salmonella*, *Listeria monocytogenes*, STEC, and relevant surrogate, indicator, and index organisms representing national and international strain diversity associated with produce. Objective 2 evaluated the strains assembled in objective 1 for (i) growth on different produce types and (ii) survival of key produce relevant controls and intervention treatments (e.g., different sanitizers). Objective 3 exposed the selected pathogen strains to different environmental and stress conditions and evaluate them for subsequent (i) growth on different produce and fruit products and (ii) survival of key produce relevant controls and intervention treatments. Lastly, objective 4 was to develop and publish standard protocols for pathogen growth under produce relevant conditions and assemble standard produce pathogen strain sets for distribution to industry as well government and academic researchers.

Key activities and tasks that were associated with objective 1 of this project included the development of a produce-relevant strain collection with input from experts from academia (n=6), government (n=5), and industry (n=8) with at least ten years of experience in food safety. The final collection is comprised of 55 strains: 23 *Salmonella enterica*; 11 *Listeria monocytogenes*; 13 STEC; and eight surrogate, indicator, and index organisms. Whole genome sequencing was completed on all isolates, and the sequences were used for phylogenetic classification. Another key activity was the development of a www-page that details this strain collection (https://foodsafety.foodscience.cornell.edu/research-and-publications/cps-strain-collection).

Key activities and tasks for objective 2 and for objective 3 included establishing standardized growth conditions and protocols for bacterial strains; these protocols were used to pre-grow the selected strains prior to sanitizer treatment or produce inoculation. Growth condition were (i) low pH (pH 5.0 for *Salmonella* and *E. coli*; pH 5.5 for *Listeria*), (ii) high salt (4 percent NaCl), (iii) low water activity (0.96 for *Salmonella* and *E. coli*; 0.95 for *Listeria*), (iv) two different growth phases (mid-log phase, stationary phase), (v) minimal medium (M9 for *Salmonella* and *E. coli*, defined medium for *Listeria*), and (vi) two different temperatures (37°C, 21°C). Using strains grown under these different conditions, sanitizer treatment (i.e., exposure to peroxyacetic acid) and inoculation experiments on produce items were conducted in triplicate for each strain

and pre-growth condition. Data collected suggests that pre-growth conditions have a considerable effect on the behavior of *Salmonella, Listeria*, and *E. coli*.

Survival after peroxyacetic acid (PAA) exposure showed limited variation among different strains when comparing strains grown under the same conditions. For example, *Salmonella* strains in mid-log phase showed log reductions (after 45-sec exposure to PAA) ranging from 5.6 to 5.7 (representing almost a million-fold reduction). In contrast, strains showed considerable differences in log reduction when grown under different conditions. For example, reductions of the four *Salmonella* strains after pre-growth to mid-log phase ranged from 7.2 to 8.0 log (representing a 10- to 100-million-fold reduction), while the reductions after pre-growth under salt stress ranged from 3.0 to 4.5 log (representing only about a 1,000- to 30,000-fold reduction after PAA treatment) (Figure 1). Similarly, *E. coli* strains grown to mid-log phase showed a consistent 8.1-log reduction after PAA exposure (with virtually no strain differences), while *E. coli* strains pre-grown under salt stress showed only a 3.5-log reduction after exposure to PAA (Figure 2). For *Listeria*, strains grown in defined medium (DM) showed little variation in log reduction after PAA exposure, with a range of 5.4- to 6.2-log reduction (representing approx. a million-fold reduction), while *L. monocytogenes* pre-grown under salt stress showed less than 2-log reduction (100-fold reduction) after PAA exposure, with a range of 0.5-to 1.4-log reduction with different strains. These data show that pre-growth conditions have a considerable effect on sanitizer-treatment survival (Figure 3). Formal statistical analyses using a crossed random effects log-link binomial proportion model specifically showed that pre-growth conditions have a larger effect on variation in log reduction due to PAA than strain or strain and condition interaction; contributions of pre-growth conditions to variation were estimated to be 99.9 percent for *E. coli*, 87.6 percent for *Listeria*, and 55.5 percent for *Salmonella*.

Overall, pre-growth conditions of bacterial inocula also had a considerable effect on subsequent pathogen growth on the selected produce items. For example, *Salmonella* pre-grown under salt-stress did not show decline in bacterial numbers after inoculation onto tomatoes and maintained the inoculated populations over seven days storage, while *Salmonella* pre-grown at 21°C showed an initial drop in numbers of up to 5 log (100,000-fold) at day zero after inoculation of tomatoes, with slow regrowth over seven days. Over the first 24 hours of incubation, condition also showed a significantly larger contribution to variation in *Salmonella* numbers than strain diversity. *Salmonella* numbers after pre-growth conditions of 21°C, glycerol, pH 5, and stationary phase did not differ significantly, but differed from numbers for *Salmonella* after pre-growth conditions of M9, NaCl, and mid-log phase. No significant difference was detected for *Salmonella* strains used for inoculation (FSL R9-5272, FSL R9-5244, FSL R9-5400, FSL R9-5502), including one avirulent *Salmonella* surrogate (FSL R9-6232) (Figure 4). For *Listeria*, pre-growth under different conditions before inoculation onto cantaloupe rind affected the length of lag phase. After seven days, *Listeria* consistently reached a final concentration of 7 log CFU/plug, regardless of pre-growth conditions. However, after 24 hours of incubation, *Listeria* strains showed a significantly larger contribution to variation of *Listeria* numbers than conditions. The surrogate organism *L. innocua* (FSL C2-0008) showed similar numbers, over the first 24 hours, as compared with FSL R9-0506 and FSL R9-5506 but differed from FSL R9-5411 (Figure 5). For *E. coli*, which was tested for survival on pre-cut romaine lettuce incubated at 7°C, bacterial numbers decreased over seven days when bacteria were pre-grown at 37°C but remained constant with no die-off when bacteria were pre-grown under 21°C. For the first 24 hours of incubation, conditions showed a significantly larger contribution to variation in bacterial numbers than strain diversity. *E. coli* pre-grown in glycerol, M9, and pH5 showed no significant difference in bacterial numbers. However, *E. coli* numbers differed significantly when pre-grown at 21°C compared to numbers when pre-grown to mid-log phase. No significant difference in

numbers was detected, after 24 hours of incubation, for *E. coli* strains used for inoculation (FSL R9-5271, FSL R9-5516, FSL R9-5517, FSL R9-5515, FSL R9-5258), including surrogate isolate FSL R9-4077 (Figure 6).

Key activities and tasks for objective 4 included developing a www-based resource that will provide access to the strain collection, including all relevant information (e.g., whole genome sequencing data) and maintenance of strain records through a www-based database (FoodMicrobeTracker), which ensures that users will continue to have access to up-to-date strain data at any time. Information on the CPS strain collection is available through https://foodsafety.foodscience.cornell.edu/research-and-publications/cps-strain-collection.

In June 2017 the PI presented interim research results at the Center for Produce Safety (CPS) Research Symposium in Denver, Colorado, to 325 attendees.

The project would not benefit other commodities; all strains collected were produce-associated (e.g., produce outbreaks, recalls, or pre-harvest environment), the challenge studies were conducted using peroxyacetic acid (a sanitizer widely used in produce industry), and fresh produce items (tomatoes, cantaloupe, and pre-cut romaine lettuce) were used in the growth and survival studies.

The project partners are CPS and Cornell University. CPS managed the project and Cornell University performed the research studies.

Goals and Outcomes Achieved

The distinct, quantifiable, and measurable outcome for this project was to assemble a collection of pathogen, surrogate, indicator, and index strains that (i) are of relevance to produce industry and (ii) have been characterized for both genetic and phenotypic diversity, facilitating the use of the strain collection for challenge and validation studies. Before this project, no such strain collection existed and there specifically was no information available on the relative effect of strain diversity and growth conditions on stress resistance and other relevant phenotypic characteristics of a standardized strain set. The project target was to assemble a strain collection of at least 50 strains and to share the associated strain information over a www-based platform, with distribution to at least 25 different companies and organizations by completion of the project. The success of the project was to be measured by (i) the number of strains distributed and (ii) the number of different companies and organizations that received strains.

Activities completed to achieve these goals include: (i) assembly of a produce-relevant strain collection of 55 strains, including *Salmonella*, *Listeria monocytogenes*, STEC, and surrogate, indicator, and index organisms; (ii) characterization of pathogens as part of the strain collection through whole genome sequencing and for their ability to survive sanitizer exposure and growth on different produce commodities; (iii) development of a comprehensive www-based resource and curated www-based database; and (iv) initial distribution of the strain collection to different companies and organizations. In the final year of the project, a total of 43 strains in the collection have been distributed to seven organizations.

The main long-term outcome measures included publication of a minimum of two peer-reviewed journal articles as well as monitoring of the number of strains distributed and the number of different companies and organizations that receive the strains. The first journal article entitled; *Development and characterization of a pathogen strain collection for produce safety applications: Pre-growth conditions have a larger effect on*

sanitizer resistance than strain diversity by Harrand et al. was submitted to the Journal of Food Protection and is under review peer review as of late 2018. The second journal article entitled; *Nature versus nurture: The effect of pre-growth conditions on survival and growth of pathogens on fresh produce* is also under review as of late 2018 and will be submitted for peer review in January 2019. The team is confident that the target of 25 different companies and organizations receiving the strains will be achieved rapidly once the strain collection is described in a peer-reviewed manuscript.

A total of 43 strains in the collection have been distributed to seven organizations. A large number of highly sought strains was provided by the Centers for Disease Control and Prevention (CDC) and, based on the initial agreement with the research team, the project team was only able to forward requests for the strains to the CDC contact rather than ship them out directly. Since early July 2018 the team has official permission to share the strains with other labs, which will facilitate the strain sharing process going forward. The team is confident that the goal of distribution to at least 25 different companies and organizations will be achieved rapidly once the strain collection is described in a peer-reviewed manuscript, which is anticipated to occur in early 2019.

The quantitative goal was a collection of 50 strains, and the strain collection developed includes a total of 55 strains, including 23 *Salmonella enterica*, 11 *Listeria monocytogenes*, 13 STEC, and eight surrogate, indicator, and index organisms. These strains have been characterized for genetic and phenotypic diversity, and the whole genome sequencing data generated during this project has been submitted to the National Center for Biotechnology Information; this includes sequence read archive data and whole genome sequencing data under Bioproject PRJNA395587. Information about the strains and the collection has been made publicly available through a dedicated www-page that can be accessed at https://foodsafety.foodscience.cornell.edu/research-and-publications/cps-strain-collection.

Key baseline data gathered include: (i) expert input on the proposed CPS strain collection, which was used to develop the final collection of 55 strains; (ii) characterization by whole genome sequencing of all 55 strains that are part of the CPS strain collection; (iii) phenotypic characterization of selected strains in the CPS strain collection, including baseline data on the effects of pre-growth conditions and strain diversity on survival after sanitizer exposure and pathogen growth on selected produce items. This project also established baseline data on the impact of growth conditions on survival after sanitizer exposure, including specific data on contributions of pre-growth conditions to variation in the measured response to sanitizer exposure, which are estimated to be 99.9 percent for *E. coli*, 87.6 percent for *Listeria*, and 55.5 percent for *Salmonella*.

Major successful outcomes for the project include: (i) development of a produce-relevant strain collection with 55 strains, including *Salmonella*, *Listeria monocytogenes*, STEC, and surrogate, indicator, and index organisms; (ii) data on genotypic and phenotypic characterization of selected organisms that are part of the strain collection; and (iii) information and access to the strain collection through a comprehensive www-based resource and curated www-based database. In the final year of the project, a total of 43 strains in the collection have been distributed to seven organizations.

Beneficiaries

The overall produce processing industry will benefit from this project, including (i) produce processors, particularly those that need to validate interventions and control strategies, and (ii) supplier companies that develop and supply treatments used as interventions (e.g., antimicrobial washes). The beneficiaries will have

access to data, which will allow for scientifically justified selection of strains and growth conditions for validation of interventions and control strategies, and a standard validated strain set to use for validation studies.

At the end of the project completion, seven different companies and organizations received strains (with a total of 43 strains distributed); at an American Type Tissue Culture Collection value of $350 per strain, the direct impact of the project to date is $15,050. Continued impact after project completion (at an estimated annual distribution of 100 strains in total to 10 organizations per year) is $35,000 per year for at least another five years. Additional economic benefits, but more difficult to accurately quantify, will arise from more rapid approval of effective interventions and controls and reduced spending on ineffective controls. Even if only 5 to 10 percent of currently used controls show limited effectiveness against target pathogens, this will result in a considerable economic impact (spending on interventions across industry is likely more than $10 million/year, so the economic impact could be as much as $0.5 to 1 million/year).

The PI from Cornell University presented final research results in June 2018 at the 9th annual CPS Research Symposium in Charlotte, North Carolina, to 300 symposium attendees. Interim results were presented previously in an oral presentation at the 2017 CPS Research Symposium in Denver, Colorado (325 attendees), and in a poster session at the 2016 CPS Research Symposium in Seattle, Washington (315 attendees). The symposium participants included California regional and national growers/shippers, retail and food service buyers, scientists, academics, produce industry representatives, and members of regulatory agencies. The annual symposium provides expert panels to discuss the research results after presentation by the researcher, which helps participants evaluate how the results can be used in their respective businesses.

Project results were disseminated at industry meetings and streamed through social media sources. Results were also made available online as follows:

1. Final report to CPS is posted on the CPS website: https://www.centerforproducesafety.org/grant_opportunities_awards.php
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3. The Board of Directors and members of the Technical Committee of CPS distribute a series of information briefs throughout the year on the website and through presentations, meetings and webinars. An example of this would be the “2017 CPS Symposium – Key Learnings” on the CPS website, available in both English and Spanish, at the following link: www.centerforproducesafety.org/key_learnings.php

Lessons Learned

One key lesson from this project is that pre-growth conditions have a greater effect (as compared to strain diversity) on survival rate of intervention treatment or survival and growth on produce; this finding may largely change how intervention and challenge studies are conducted and may lead to a move from “multi-strain cocktails” (with all strains grown under one condition) to “multi-growth condition cocktails.”

Overall, the project worked as planned and all project deadlines were met. Positive experiences include the willingness of experts to provide input on the strain collection and selection of produce items for growth and survival studies as well as the willingness of a variety of institutions and organizations to provide strains. Organizations that provided strains include the Food and Drug Administration; Centers for Disease Control

and Prevention; United States Department of Agriculture; Wisconsin State Laboratory of Hygiene, Trade, and Consumer Protection; Texas Tech University; STEC Center (Michigan State University); University of California, Davis; and University of Florida. The team is confident that involvement of CPS in this project was critical to facilitate these broad collaborations.

A negative experience and unexpected outcome of the project was that whole genome sequencing data showed that three *Salmonella* isolates initially received did not represent the correct strains, as shown by whole genome sequencing, which delayed part of the project because these strains had to be replaced.

Distribution of the strain collection was not as extensive as originally planned; replacing the three incorrect *Salmonella* strains for the final strain collection required considerable time, and fewer strains in the strain collection were distributed to fewer end-users during the project term. The lesson learned is that further promotion of the strain collection resource is needed beyond the existing web page. The project team has recommended to CPS that they help promote this "CPS Strain Collection" resource on their home page.

Additional Information

Information on the strain collection can be accessed at the "CPS strain collection."
www.foodsafety.foodscience.cornell.edu/research-and-publications/cps-strain-collection/

The following websites provide additional resources on the final reports and symposium proceedings:

Center for Produce Safety: www.centerforproducesafety.org/resources.php
Produce Marketing Association: www.pma.com/topics/food-safety/center-for-produce-safety
Western Growers Association: www.wga.com/

Initial project findings also were presented in 2017 in a poster entitled: "Characterization of a Pathogen Strain Collection to Allow for Improved Validation of Sanitizer Efficacy in the Produce Industry" at the annual meeting of the International Association for Food Protection as well as at the annual conference of the New York State Association for Food Protection.

See Attachment for Figures 1–6 for additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 67	**Project Title:** Climate-Smart Agriculture for Specialty Crops: Partnership Building with Australia and Chile & Climate-Smart Agriculture Summit/Consumer Education	
Grant Recipient: California Department of Food and Agriculture	**Grant Agreement No.:** SCB15067	**Date Submitted:** December 2018
Recipient Contact: Josh Eddy	**Telephone:** (916) 654-0462	**Email:** josh.eddy@cdfa.ca.gov

Project Summary

Climate change is a pressing issue that is and will continue to challenge sustained agricultural productivity around the world. A strong base of scientific studies has documented increasing average global temperatures and weather variability. With anticipated continual warming, the state's agricultural sector faces greater risks of drought and reduced snowpack and natural groundwater recharge, hotter summer days, and fewer winter chill hours. This likelihood for increased climate variability and increased frequency of climate extremes has challenged California specialty crop growers to maintain current yields.

The purpose of this project was to further the application of climate-smart technologies, methodologies and management practices within California's specialty crop sector. Climate-smart technologies and practices used in agricultural production can help to adapt to changing climate conditions and reduce greenhouse gas emission contributions from farms. Bringing together farm organizations, research institutions and other stakeholders in California to learn more about the use of on-farm climate-smart technologies, methodologies and management practices implemented in Australia and Chile facilitated the diffusion of new ideas and innovations to specialty crop growers and producers across the state.

In addition, this project provided the opportunity for the California Department of Food and Agriculture (CDFA) to convene a summit in California, focusing on soil health for the specialty crop sector. The summit/consumer education segment highlighted the positive economic impacts/benefits of soil health practices undertaken by farmers and the importance of these attributes to the consumer and trade sectors.

The project was important and timely for several reasons. California continues to suffer from a severe and ongoing six-year drought and record-setting high temperatures, which are impacting yields and growing practices of specialty crop production. The prolonged drought limits surface water availability and has led growers to rely on pumping from finite groundwater reserves. Investigating and experimenting with innovative water management and irrigation technologies and practices are critical to assisting growers in adapting to changing water availability. urther, climate-smart management practices, and particularly those focused on building soil health, are gaining international attention for the possible multi-benefits of building agricultural resilience, maintaining and increasing yields under changing climate conditions, and contributing to emission reductions and carbon sequestration. This project has built international collaboration with Australia and Chile to share knowledge and experiences with on-farm climate-smart technologies, methodologies and management practices that will assist Californian specialty crop growers to build climate resilience. Further this program supported a climate smart agriculture summit with the purpose of accelerating the scaling-up of climate smart agricultural practices, which provide specialty crop producers a niche marketing opportunity and support the sustainability of specialty crop production.

This project built upon the 2013 Specialty Crop Block Grant Program (SCBGP) Project 66*: Climate-Smart Agriculture for Specialty Crops – Partnership with the Netherlands and Israel*. CDFA and its California Climate Partners worked with the Netherlands and Israel to share knowledge around the challenges of drought management and limited water resources. This project complemented and enhanced previously completed work by furthering the application of climate-smart technologies, methodologies and management practices within California's specialty crop sector. This was accomplished through the continuation of webinars, the ongoing development of a climate website, outreach, and consumer/trade education as a result of the summit activity.

Project Approach

This project consisted of three core activities with the purpose of furthering the application of climate-smart technologies, methodologies and management practices within California's specialty crop sector. A summary of each of the activities is as follows:

Climate Smart Agriculture Delegation to Australia (March 17-25, 2017):
CDFA led a delegation of six climate partners representing the specialty crop sector, or working directly within specialty crop sector. A self-paid representative from the University of California also participated for a portion of the trip. The trip to Australia allowed climate partners to better understand research, technologies and lessons learned, including monitoring and evaluation tools and established protocols for best management practices, for improving water efficiency and building soil health which could benefit specialty crop producers.

As part of the Australia activity component, CDFA conducted a post trip webinar on June 19, 2017 focusing on water management and technologies for specialty crops. The webinar featured the participation of representatives the delegation visited while in Australia.

Climate Smart Agriculture Delegation to Chile (November 25-December 2, 2017):
CDFA led a delegation of 10 climate partners representing the specialty crop sector, or working directly within specialty crop sector. The trip to Chile allowed climate partners to better understand drought management and adaptation strategies used in the country for the benefit of specialty crop producers in a Mediterranean Climate similar to California.

As part of the Chile activity component, CDFA conducted two webinars (October 30, 2017 and April 25, 2018) occurring prior to and following the Chile delegation. The webinars focused on climate change adaptation strategies as well as precision agricultural technologies applicable to specialty crop growers.

Scaling-Up Climate Smart Agriculture Summit (September 11-12, 2018):
CDFA convened a climate smart agriculture summit focusing on soil health for the specialty crop sector in addition to other agricultural sectors. Other industry funds supported activities not associated with the specialty crop sector. The summit was attend by a variety of climate stakeholders that included California specialty crop producers, farmers, government officials, multinational corporations, non-governmental organizations and climate entities. The summit highlighted the importance that soil health and on-farm climate smart practices have in providing a niche marketing opportunity for specialty crop producers.

Webinar (December 5, 2017):
In further support of the project, CDFA conducted an additional webinar with international partners (Mexico, Canada) on December 5, 2017 focusing on soil and as a climate smart agricultural strategy. This webinar contributed to furthering the outreach and dissemination of climate-smart technologies, methodologies, and management practices within California's specialty crop sector.

The Scaling-Up Climate Smart Agriculture Summit (September 11-12, 2018) was the only core activity of the project which benefitted commodities other than specialty crops. This activity was supported through funding from a variety of outside sources to create a two-day event. All costs were tracked to ensure that SCBGP funds were used to solely enhance the competitiveness of specialty crops.

In completing the core activities of this project, CDFA partnered with 17 organizations. These partners provided significant contributions which included: outreach and dissemination of climate smart agricultural practices which would directly benefit specialty crop producers; participation in webinars and events to promote promoting innovations; and input on key visits (delegation missions) to better enhance understanding of climate-smart practices benefiting specialty crop growers.

One of the primary on-going contributions project partners provided to the project is the role of supporter/champion of climate smart agricultural practices for the specialty crop sector. Participants within the activities are leading representatives, or organizations, working within the specialty crop sector. Their experience in participating in these activities (delegation missions) helped to further connect other specialty crop farmers to technologies, methodologies and management practices that can assist California specialty crop growers in being more adaptive to climate change.

Project partners played a critical role in facilitating the delegation missions to Australia and Chile. The expertise and experience of the partners was a direct contribution to the success of the project. They also facilitated specialty crop activities associated with the Scaling-Up Climate Smart Agriculture Summit.

Goals and Outcomes Achieved

The Expected Measurable Outcomes for this project are as follows:

Goal: Enhance the competitiveness of specialty crops through more sustainable, diverse, and resilient specialty crop systems. All individuals participating in the outreach and education programs will gain knowledge about climate-smart agriculture. Performance Measure: Number of growers/producers that gained knowledge about science-based tools through outreach and education programs. Benchmark: The benchmark will be the results of the 2013 SCBGP Project 66: 24 external specialty crop stakeholders, 5,000 individuals were exposed to outreach efforts, and more than 100 participated in webinars, workshops, etc. Target: 35 external specialty crop stakeholders, 6,000 individuals exposed to outreach efforts, and 300 participated in webinars, workshops, etc.

The following activities were completed in order to achieve the performance goals and identified measurable outcomes within this project: climate webinars, outreach, and a climate smart agriculture summit. A climate website, another activity to meet performance goals, is also an ongoing activity.

Climate webinars: CDFA conducted four climate webinars (June 2017, October 2017, December 2017 and April 2018). Each of these webinars focused on sharing knowledge and experiences associated with on-farm climate smart practices for specialty crops. Total attendance/viewership on webinars was 612 individuals.

Climate smart agricultural outreach: CDFA conducted 20 social media posts on a blog site (CDFA Planting Seeds) focusing on collaboration with Chile, Australia, the Climate Summit, and other climate smart activities associated with specialty crops. Total viewership of the social media post was 6,169 – exceeding performance target.

Climate smart agricultural summit: CDFA conducted an agricultural summit in September 2018. The summit was attended by 137 individuals and generated outreach as part of the climate smart agricultural outreach.

As part of the overall project, 17 external specialty crop stakeholders were directly introduced to climate smart agricultural practices (delegation participants) and an additional 40 were introduced to climate practices as part of the climate summit. This metric exceeded performance target.

No long-term outcome measures were included as part of this project. However, CDFA continues to work on the development and implementation of a climate website identified as an activity to achieve performance goals. While the website component did not impact the performance measurable outcomes, the activity is still seen as being important to the overall effort to share knowledge and experiences with on-farm climate-smart technologies, methodologies and management practices that will assist Californian specialty crop growers to build climate resilience.

In evaluating the performance measure for this project, the activities conducted to achieve the targeted goals were appropriate. CDFA established the following project goal: Enhance the competitiveness of specialty crops through a more sustainable, diverse, and resilient specialty crop systems. The activities conducted to measure achievement generated specific outcomes regarding the number of individuals exposed to outreach efforts (social media/climate summit attendance); participated in webinars/workshops and; external stakeholders directly introduced to climate smart agricultural practices. This collected data (activity results) demonstrates achievement related to the overall goal of enhancing the competitiveness of specialty crop producers by sharing knowledge and experiences with on-farm climate-smart technologies, methodologies and management practices to build climate resilience.

One of the primary on-going contributions and a successful outcome of the project was the role of participants as supporters/champions of climate smart agricultural practices for the specialty crop sector. Participants within the activities (delegation missions) were leading representatives, or organizations, working within the specialty crop industry. Their experience in participating in these activities (delegation missions) helped to further connect other specialty crop farmers to technologies, methodologies and management practices that can assist California specialty crop growers in being more adaptive to climate change.

This project resulted in 17 external specialty crop stakeholders becoming supports/champions of climate smart agricultural practices for the specialty crop sector.

Another successful outcome was the direct outreach on climate smart agricultural practices for specialty crop producers. With the webinar and outreach activities (blog) more than 6,781 individuals were engaged with

information to enhance the competitiveness of California's specialty crop industry through building awareness on climates smart agricultural practices.

Beneficiaries

The groups and other operations that benefited from the complementation of this project's accomplishments are the individuals and organizations that work within (or work directly with) the specialty crop sector. For the delegation missions, representatives from a diversity of specialty crop products were represented, including, but not limited to: almonds; walnuts; pistachios; tomatoes, peppers, onions, wine grapes, olives, canned peaches, apricots, raisins, citrus, prunes, figs, and garlic. Organizations that work directly with specialty crop farmers included: The State Water Resources Control Board, the Public Policy Institute of California, the United States Department of Agriculture Natural Resources Conservation District, the Center for International Trade Development, the Buy California Marketing Agreement and the Resource Conservation District of Monterey County, Carbon Cycle Institute and the California Farm Bureau Federation.

The beneficiaries of this project are the specialty crop growers in the state, approximately 45,646 farms producing on more than 4,338,625 acres. These specialty crop farms contribute less than 4 percent of California's total greenhouse gas emissions but have a great potential to contribute to the agricultural sector's role in carbon sequestration. In looking at the potential adaptation of climate smart agricultural practices, reductions in greenhouse gas emissions can also have a positive public impact. The ability for specialty crop farmers to reduce greenhouse emissions and calculate greenhouse gas reductions is a marketing/sales enhancement for specialty crop producers and is also a public benefit for the state.

Lessons Learned

One of the key lessons learned that illustrates positive results is the involvement of project partners to successfully implement programs. The project partners had the expertise and experience that contributed positively to the overall project.

Regarding delegation missions, the partnership and contribution of the contacts within the U.S. Embassy in Chile and Australia were important to securing in-country market representation and meetings that directly resulted in a successful trip.

An experience learned by project staff that can benefit future awardees is that activities developed to demonstrate progress on expected measurable outcomes can become challenging within themselves. For this project, project staff struggled with completing an activity (climate website) that would help to achieve expected measurable outcomes of the project. While several separate activities were completed to demonstrate progress and meet expected measurable outcomes, one element (climate website) remains ongoing. The climate website was not completed because of staffing needs to develop database and unanticipated costs of website design and tracking. The lesson learned is that unanticipated changes and costs can impact activities specifically developed to measure progress on outcomes. While this project had several activity components to measure progress, one activity (website) was unable to be completed.

One unexpected positive outcome of this project, is the international collaboration and commitment of foreign governments to climate smart agricultural practices. Over the course of this project and the previous 2013 Project 66, CDFA has had the privilege of working with many national and sub-national governments

including: Australia, Mexico, Israel, Baja Mexico, the Netherlands and France. These connections have leveraged the work of SCBGP projects to further engagement and planning on climate smart agricultural practices for specialty crops.

Additional Information

Information on project activities are available at:

CDFA's Planting Seeds Blog: https://plantingseedsblog.cdfa.ca.gov/wordpress/

CDFA's Climate Webinar Site: https://www.cdfa.ca.gov/climatesmartag/

CDFA's Scaling-Up Climate Smart Agriculture: https://www.cdfa.ca.gov/climatesmartag/scalingup/info/

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 68	**Project Title:** Addition of Key California Specialty Crops into the COMET-Farm Tool	
Grant Recipient: California Department of Food and Agriculture	**Grant Agreement No.:** SCB15068	**Date Submitted:** December 2018
Recipient Contact: Amrith Gunasekara	**Telephone:** (916) 654-0433	**Email:** Amrith.gunasekara@cdfa.ca.gov

Project Summary

The agricultural sector in California, which is predominantly specialty crops, is responsible for contributing between 6 and 7 percent of the state's total greenhouse gas (GHG) inventory. Direct GHG reductions from California specialty crop farms is an achievable goal. Specialty crop farmers in California also have the potential to capture atmospheric carbon dioxide emitted from other sectors as well, by sequestering carbon in the soils and woody plant material through conservation management practices. However, several important specialty crops are not yet included in COMET-Farm, and currently there are no other tools that allow specialty crop farmers to quantify GHG reductions. The specialty crop agriculture sector in California can benefit from reduced atmospheric GHGs by improving the farmer's overall performance, contribution to the environment and long-term sustainability, while at the same time providing multiple benefits to the environment. Also, being able to evaluate the GHG reductions of specialty crop management practices is increasingly important for a farmers overall marketing strategy. This project provided specialty crop farmers with a user-friendly, yet highly quantitative GHG accounting tool that can help them manage their farms consistent with environmental stewardship principles resulting in potential economic benefits to California specialty crop farmers.

This project did not enhance the competitiveness of non-specialty crops.

This project built upon the 2014 Specialty Crop Block Grant Program (SCBGP) Project 61: *Addition of Ten Specialty Crops into the COMET-Farm Tool*. This project included different specialty crops than those added to the COMET-Farm Tool in the 2014 SCBGP Project 61 and included the improvement of one existing specialty crop. By focusing on a different selection of specialty crops and improving one, this project complimented and expanded upon the previous project, rather than duplicating the existing work.

COMET-Farm is a web-based full GHG accounting tool used in California and nation-wide to assess the potential GHG reductions and carbon sequestration from agricultural conservation practices.

This project received supplemental support from the United States Department of Agriculture (USDA), National Resource Conservation Services (NRCS) through a separate funding mechanism. NRCS provided supporting funds for outreach efforts to NRCS state and field offices, extension services, grower associations, producers and other interested parties to extend use of the tool throughout the state of California once the specialty crops have been added to the tool. This effort was a critical part of this collaboration but was funded by NRCS through a separate contract and was not duplicative of the SCBGP funding for this project.

The benefits of this project to California's specialty crop industry will continue after the completion of the grant. The addition of the specialty crops to COMET-Farm will be a valuable tool to specialty crop farmers as

they will be able to assess the environmental benefits, including quantifiable GHG reductions, of various farming practices. Specialty crop farmers can benefit from the on-farm energy audit provided by COMET-Farm, be eligible for financial incentives for practices that reduce GHG emissions, and validate their environmental stewardship activities for potential marketing purposes.

This project was intended to support both the Healthy Soils Initiative and to maintain concurrency with the CDFA Fertilizer Guidelines Program. Increasing the number of crops that can be assessed in the COMET-Farm and COMET-Planner tools widened the number of farmers who could interface with the Healthy Soils Initiative and increased the total land area where the goals of the Healthy Soils Initiative may be implemented. Maintaining concurrency with the Fertilizer Guidelines Program will expand opportunities for producers to leverage the benefits of both programs.

This project utilized the same analytical methods, modeling framework, and data sources as the 2014 SCBGP Project 61, through which Colorado State University added 22 high-value specialty crops to the COMET-Farm tool, increasing the amount of farmland that could be assessed in the tool from approximately 60 percent to approximately 85 percent. Through that project the COMET-Planner tool was positioned to be applicable to assess conservation practices on a significantly larger amount of cropland and grassland in California than previously.

Project Approach

The goal for this project was to add at least four and up to seven specialty crops to the COMET-Farm system. Five new crops were added to the system:

- peaches and nectarines
- cherries
- olives
- carrots
- avocados

These crops were all in the final testing process within the COMET-Farm system and made available to users on the website: http://cometfarm.nrel.colostate.edu/.

The steps to accomplish this were as follows:

- Literature Review: Review of scientific, industry, and extension literature was completed to compile a list of experiments that could be modeled effectively for use in building input parameters for the DayCent model. It was determined that not enough experimental data were available at the present time to add plums, prunes, and apricots to the tool. The remaining crops were prioritized according to the resources available, in rank of their economic importance.
- Build dataset of experiments, conduct model initial parameterization: The products of the literature review were leveraged to build the initial DayCent model parameterization datasets for each of the crops.
- DayCent model verification, Model Testing, and Evaluation: In order to complete this work, data was utilized on general regional cropping practices for the specialty crops and modeled in Daycent the actual crop yields by utilizing spatial datasets generated within the state of California which

showed on a parcel by parcel basis where crops were grown. These data were used to adjust the overall plant production in the tool to match regional plant production.

- COMET-Farm Integration and Testing: The products of the model verification work were added to the COMET-Farm system and will be the basis for the inputs driving the DayCent model when future users attempt to model these five new crops in the system.

Staff from the USDA NRCS, and University of California Extension supported this effort by providing invaluable technical guidance, feedback, literature, and connections with growers during field trips to learn and understand plant production techniques specific to each of these five specialty crops.

Goals and Outcomes Achieved

By adding five new specialty crops to the COMET-Farm system, the goal of adding at least four specialty crops under this project was accomplished. Due to privacy restrictions the team was unable to precisely asses the number of unique users. However, it was predicted that there were approximately 26 unique users that had modeled these new crops in the COMET-Farm system since the crops were added. Both COMET-Planner and COMET-Farm experienced a monthly increase in users in the last calendar quarter of 2018. The team continued to conduct monthly monitoring of the use of COMET-Farm and COMET-Planner tools to assess the uptake and use by users of the tool based in California.

In the three months prior to completing this project, 285 users per month from California utilized the COMET-Planner tool and 76 users per month from California utilized the COMET-Farm tool. These numbers were regularly monitored. The project team expects these numbers to increase after completing outreach and public education to users in California regarding the availability of the new crops in the system. Although some parts of California have cropping activity year-round, this period of analysis occurs at the peak activity of the summer production season, and these number were expected to increase as the summer growing season ended and producers devoted more time to tools like COMET-Planner and COMET-Farm.

Adding these crops to the COMET-Farm system expanded the amount of additional cropland area on which the GHG benefits of conservation practices can be assessed by approximately 267,000 acres, based on the 2016 Agricultural Commissioner's Report:

- Peaches and Nectarines: 75,000 harvested acres
- Cherries: 38,000 harvested acres
- Carrots: 62,000 harvested acres
- Olives: 41,000 harvested acres
- Avocados: 51,000 harvested acres

In total, these crops were valued in 2016 in California at a total of $2.27 billion.

Beneficiaries

Specialty crops producers and associated partners growing peaches and nectarines, cherries, carrots, olives, and avocados in the state of California will be able to immediately utilize the COMET-Farm tool to estimate the GHG benefits of conservation practices. The addition of these specialty crops to the COMET-Planner tool will allow for a more comprehensive picture into the benefits of conservation practices when assessed at the regional level.

Producers growing crops on approximately 267,000 acres of cropland in the state of California, who previously could not, will now be able to utilize the COMET-Farm tool to assess the GHG benefits of conservation activities on their fields. This project benefitted approximately 2,850 growers.

Lessons Learned

The principal lesson learned from this project was that efforts to quantify the GHG balance of these crops and associated cropping systems would benefit from additional efforts to measure and publish specific details on basic plant physiology and plant production, including biomass allocation in orchard crops, aboveground biomass accumulation, belowground biomass accumulation, and carbon-to-nitrogen ratios in different parts of the plants. Relatively little of these data were available for configuring plant production models used in the COMET Tools, and more of these data would improve the quality of the modeling.

There did not appear to be sufficient published data on the growth of plums, prunes and apricots to be able to adequately model these crops for addition to the COMET-Farm system. An expanded literature review into the gray literature, or partnering with industry groups, could uncover new data sources that could not be identified at this time.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 69	**Project Title:** Analysis of Heavy Metals Based Agrochemicals in Specialty Crops	
Grant Recipient: California Department of Food and Agriculture	**Grant Agreement No.:** SCB 15069	**Date Submitted:** December 2018
Recipient Contact: Maryam Khosravifard	**Telephone:** (916) 228-6829	**Email:** Maryam.khosravifard@cdfa.ca.gov

Project Summary

The Pesticide Residue Laboratory (PRL) utilizes various equipment and instruments in the work process. Currently, the PRL does not have the Inductively Coupled Plasma- Mass Spectrometer (ICP-MS) technology and must refer all heavy metals analysis such as arsenic, mercury, cadmium, copper, and lead to the Environmental Safety Laboratory (ESL) as it's equipped with the expertise and instrumentation. Recently, the ESL has analyzed specialty crop samples from the PRL with potentially harmful heavy metals such as arsenic, from application of arsenic based pesticides, such as Monosodium methanearsonate (MSMA). MSMA is an organic arsenical pesticide currently registered for use in the United States. MSMA is a broad-spectrum herbicide used in agriculture, combining selectivity, low weed-resistance, and cost-efficiency. Therefore, making it attractive for growers to use, even in cases when pesticide use is not allowed.

Currently, the ESL uses the Inductively coupled plasma optical emission spectroscopy (ICP-OES) instrument for metals analysis. The ICP-OES technology is outdated. It does not have the capability for the low detection limit needed in the analysis of crops such as strawberries and leafy green vegetables. The data results confirmation is also not definitive, and the sample preparation is time consuming. Current instrument capability is a maximum of 50 samples per day, whereas the ICP-MS capability is 50 samples per hour.

The goal of this project was to purchase a new ICP-MS instrument for the ESL. Supplying the ESL with a second ICP enables development of analytical methodologies, which affords the efficiency in the testing produce and accuracy at low concentration levels for heavy metals analysis. Increasing the overall capability, efficiency and data quality ensures adulterated specialty crops are removed from the channels of trade thus protecting the marketing integrity of the specialty crops and consumers. The process improvement and capability enhance the competitiveness of California specialty crops as consumers' confidence is increased with the knowledge and assurance that their produce is meeting the food safety standards.

The California Department of Pesticide Regulation and Agricultural Commissioners in each county are statutorily tasked to ensure that products are used in accordance with their label directions. Also, they ensure that specialty crops with pesticide residues above their established tolerances, or contain illegal residue are removed from the market place for food safety concerns. These agencies conduct investigations of illegal pesticides use and send samples to the PRL for analysis.

Providing a more advanced and sensitive ICP-MS instrumentation will enhance the speed, accuracy, and reliability of detection method for the program. The overall accuracy and efficiency improvement will benefit the consumers and specialty crop growers as the regulatory programs will be able to take timely enforcement action and boosts consumers' confidence in the integrity and safety of California specialty crops.

This project did not build upon a previously funded Specialty Crop Block Grant Program project.

Project Approach

The ICP-MS instrument was purchased in June of 2018. The instrument was received by PRL in September of 2018. Project staff are currently working with electrical contractors to complete the necessary electrical upgrades. Staff are hoping to have the instrument completely installed by January and validated by the end of February 2019. Analyzing specialty crop samples will start by March 2019 and will be ongoing.

This project did not enhance the competitiveness of non-specialty crops. Only specialty crops will be analyzed using the ICP-MS instrument.

Goals and Outcomes Achieved

The program has been working on the procurement of the ICP-MS and received the instrument mid-September of 2018. However, due to contracting process delays, staff have not been able to complete the electrical upgrades necessary to install the instrument yet. Currently the contractors are in the process of upgrading the area where the instrument will reside. Once this step is completed the vender will install the instrument in early January 2019.

Currently, the ESL processes about 50 samples per day. Once the ICP-MS instrument is installed and validated, the ESL will potentially be able to analyze 50 samples per hour. There have been no tests as of yet so no comparison can be made.

Beneficiaries

The immediate beneficiary of increased sample analysis capacity and speed is the California specialty crop industry and consumers. The ability to test specialty crops for pesticides reliably will substantially enhance their value and influence potential revenue growth on a national and global market scale. Consumer demand for specialty crops that meet pesticide residue safety standards has shown tremendous growth, providing market incentives for farmers across a broad range of products.

State Residue Monitoring data provided by the PRL consistently demonstrate that California’s food supply is among the safest in the world. In 2016, the PRL conducted approximately 3,600 samples in the State Residue Monitoring program. Of these, 891 samples had incurred residues and only 174 samples (5 percent) contained incurred residues that were tolerance violations.

Once the ICP-MS instrument is up and running, staff expect to analyze up to 400 samples per day.

Lessons Learned

Similar projects could benefit from this project by working with the instrument vendor prior to ordering to confirm electrical and space requirements. This would have saved staff time and the instrument could have already been installed and analyzing specialty crops.

The goal of analyzing up to 50 samples per day has not been achieved because the instrument has not been installed. Staff are confident that once it is installed and validated, the goal will be achieved.

Additional Information

No additional information.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.: 70	**Project Title:** Improving Process Efficiency and Expanding Capability in Analysis of Genetically Modified Organisms in Specialty Crops	
Grant Recipient: California Department of Food and Agriculture	**Grant Agreement No.:** SCB15070	**Date Submitted:** December 2018
Recipient Contact: Tiffany Tu	**Telephone:** (916) 228-6830	**Email:** Tiffany.tu@cdfa.ca.gov

Project Summary

The Food Safety (FS) programs at the Center for Analytical Chemistry, California Department of Agriculture (CDFA), screen domestic and imported specialty crop produce for all classes of agrochemicals and genetic materials and in cooperation with regulatory agencies, assure the quality and safety of California's food supply. The Pesticide Residue (PR) laboratory within the FS program supports other CDFA programs such as the State Organic Program (SOP). One of the SOP's mandates is to ensure the integrity of organic specialty crops within the state of California while maintaining sufficient regulatory oversight. Recently, the SOP has requested the PR laboratory to start testing for genetically engineered produce. The use of genetically modified organisms (GMOs) is prohibited in organic products.

The PR laboratory utilizes various equipment and instruments in the work process. For the GMO project, the laboratory uses Polymerase Chain Reaction (PCR) machine to detect and quantitate genetically engineered materials or foreign DNA inserted into the plant's genome. PR laboratory has one old PCR machine used for the analysis which is problematic because of the work stoppage when the only machine breaks down. As part of the sample extraction procedure, dilution of micro-volumes is required. Preparing the real-time PCR plates manually is difficult due to the small well size and the complexity of the plate setup. Furthermore, part of the work process is the thoroughly cleaning of the laboratory equipment used in preparing samples to prevent contamination. Currently, laboratory staff spend a lot of time scraping, rinsing and drying the chopper used in samples homogenization.

The goal of this project was to purchase a new QuantStudio PCR machine, the liquid handling workstation, and a high temperature dish washer for the PR laboratory. Having a liquid handling workstation would reduce GMO sample analysis time and improve quantitative accuracy by automating the PCR well plate setup. Supplying the PR laboratory with these pieces of equipment would improve the process and enhance the competitiveness of California specialty crops as consumers' confidence is increased with the knowledge and assurance that their organic produce is free of prohibitive materials such as GMOs.

Demand for organically produced goods has shown tremendous growth in the past years. This growth might be attributed to the consumers' strong resistance to the use of synthetic pesticides and genetically modified materials in conventional products. The SOP is statutorily mandated to enforce the United States Department of Agriculture's (USDA) organic regulations among which is the requirement that organic produce must be free from prohibitive materials such as GMOs. The goal of the PR laboratory is to support the SOP by testing targeted organic produce for the presence of GMO.

This timely project equips the FS laboratory with proper process apparatus thus enhances programmatic efficiency and improves data quality ultimately.

This project did not build upon a previous funded Specialty Crop Block Grant Program project.

Project Approach

PR staff purchased the major equipment immediately after the award was announced. Staff started to use the fast-cycle dishwasher as soon as it was installed, and it has been a big help with the efficient work flow. One unexpected benefit of having the high-power dishwasher is the safety improvement as staff do not have to lift heavy blades of the large-samples homogenizer to clean.

The PCR machine and the liquid handling workstation have not been installed at this time. Project staff are currently working with electrical contractors to complete the necessary electrical upgrades. Staff are hoping to have the equipment completely installed by January and validated by the end of February 2019. Analyzing specialty crop samples will start by March 2019 and will be ongoing.

This project did not enhance the competitiveness of non-specialty crops. Only specialty crops will be analyzed using the equipment.

Goals and Outcomes Achieved

Program staff procured the PCR machine, dishwasher, and liquid handling workstation and received the equipment by August 2018. However, due to contracting process delays, staff have not been able to complete the electrical upgrades necessary to install the PCR machine and liquid handling workstation. Currently the contractors are in the process of upgrading the area where the equipment will reside. Once this step is completed the vendor will install the equipment in January 2019.

Currently, the PR laboratory processes about 30 samples per year. Once the PCR machine and liquid handling workstation have been installed and validated, the PR laboratory will potentially be able to analyze 300 samples per year. Currently no tests have been completed so no comparison can be made.

Beneficiaries

The immediate beneficiary of increased sample analysis capacity, speed, and accuracy is the California organic specialty crop industry and consumers. The SOP is statutorily mandated to protect consumers, producers, handlers, processors, and retailers by monitoring, and enforcing the USDA organic regulations. Organic produce must be free from prohibitive materials such as synthetic pesticides and genetically modified materials. The ability to more quickly and accurately test specialty crops will substantially decrease the potential for quarantines and public safety incidents that may result in loss of revenue for specialty crop farmers.

According to the 2015-2016 California Agricultural Statistics Review (https://www.cdfa.ca.gov/statistics/PDFs/2016Report.pdf), in 2015 there were 5,600 acres of squash (both conventional and organic) were planted with a total value of $29,826,000 for California.

Once the PCR machine and liquid handling workstation have been installed and validated, the PR lab will potentially be able to analyze 300 samples per year.

Lessons Learned

Similar projects could benefit from this project by working with the equipment vendor prior to ordering to confirm electrical and space requirements. This would have saved staff time and the equipment could have already been installed and analyzing specialty crops.

The goal of analyzing up to 300 samples per year has not been achieved because the equipment has not been installed. Staff are confident that once the PCR machine and liquid handling workstation are installed and validated, the goal will be achieved.

Additional Information

No additional information.