OREI Project Details

Award Year 2016

18 Research Projects

PROJECT INDEX

Strengthening Organic Farming Infrastructure Through Consumer Education, Market Development, and Integrated Extension and Research Programs in the Southeast

Accession No.	1010960
Project No.	2016-04437
Agency	NIFA AL.X\
Project Type	OTHER GRANTS
Project Status	NEW
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Proposal No.	2016-04437
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Term Date	31 AUG 2020
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Grant Year	2016
Investigator(s)	Kpomblekou-A, K.

NON-TECHNICAL SUMMARY

The proposal supports OREI 2016 Program goals. It strengthens organic agriculture development, screens crop varieties appropriate for the Southeast (SE), identifies market, develops on-farm research for the benefits of organic producers, addresses socioeconomic issues related to organic agriculture in the SE, and synchronizes research and extension activities in the SE. The United States leads the world in organic agriculture market; however, most of the organic certified operations (OCO) are in the Northeast, Midwest, and California. Although sales of organic products in the U.S. reached \$35 billion in 2013 and are expected to grow at an annual rate of 14% until 2018, only 650 farms were listed in the SE as OCO in 2011. This multi-regional proposal\'s long-term goal is to facilitate development of a strong and vibrant organic farming industry throughout the SE through consumer education, market development, an effective educational support for producers and extension agents. The proposal\'s objectives are to: 1) Conduct consumer education and market research on organic produce with focus on Alabama, 2) Provide organic producers with site specific recommendations on selected vegetable crops, 3)Develop a participatory extension and evaluation program to support organic food systems, and 4) Build a database for organic information for the benefits of organic farmers. The project brings together four land-grant universities in the SE, Oregon State University, and Alabama Sustainable Agriculture Network to address critical issues of concerns to organic producers. By project\'s end, we anticipate raising consumers\' awareness of organic produce by 20% and doubling the number of OCO.

OBJECTIVES

The long-term goal of this integrated proposal is to facilitate development of a strong and vibrant organic farming industry in the southeastthrough consumer education, market development, and effective educational support for farmers, extension agents and integrated extension and research programs.The supporting outreach objectives are to:Conduct consumer education and marketing research on organic produce focusing on Alabama,Provide organic growers with site specific recommendations on selected vegetable crops,Develop a participatory extension and evaluation program to support organic food systems, andBuild a database for organic information for the benefits of organic farmers in all regions of the nation. **Project Methods** The project will use four different approaches to reach its goals. The project will conduct workshops in major cities of Alabama to educate consumers on the health benefits of consumption of organic fruits and vegetables. A major emphasis will be

placed on consumer recruitment, delivery contents, and effectiveness of delivery. It will also identify market participants along the marketing chain of organic foods in Alabama. Moreover, it will conduct a market chain analysis of organic foods, identify sources of organic foods, market intermediaries participating in the marketing chain, consumers of organic foods, factors affecting consumption of organic foods, consumers characteristics and perceptions affecting the sales of organic produce and evaluate the growth in market sales of organic foods and the market, and institutional factors that influence marketing of organic foods in Alabama. A pilot study will be conducted in Tuskegee to test three candidate organic pesticides against two of the most important major pests of various vegetable crops (squash and tomatoes, sweet potato, southern peas) in the southeast followed by a three-year on-farm multi-locational research trials throughout the southeast. An economic analysis will be carried out using cost/benefit and optimization models, results of which will enable us to identify the most profitable commodity for each state and comparison across the southeastern region. A comprehensive and region wide organic extension education campaign will be conducted using the transformation educational model that includes four implementation stages (technology transfer stage, service stage, facilitation stage, and high impact program) and with a harmonious communication strategy. Annual conferences will be organized to disseminate knowledge gained from the project. A database for organic information for the southeast will be built to benefit all organic producers in the US. We will make available to growers articles, videos, and webinars. Progress 09/01/16 to 08/31/21 Outputs Target Audience:The audience was organic growers, restaurant managers, extension personnel, students, and consumers in the Southeast United States. Changes/Problems:No major changes were made to the project. What opportunities for training and professional development has the project provided?As part of objectives 1 and 3, we organized Food & Farm Forum and Youth Food & Farm Forum. A Central Alabama CRAFT (Collaborative Regional Alliance for Farmer Training Network was created to conduct peer-to-peer, on-farm, and farmer-led training that included intentional space for community-building and social support with the aim of building a network that provided existing and aspiring organic farmers in Central Alabama more effective opportunities to build skills, exchange knowledge, and build community with one another. We provided Site Specific Recommendations and Farm Visits with Organic Grower Partners on the use of organic crop varieties and OMRI approved throughout the Southeast. We engaged grower partners in teaching roles throughout winters to tackle specific crop and regional wisdom, knowledge and problem identification. How have the results been disseminated to communities of interest?Our findings have been disseminated to organic growers and consumers throughout the Southeast. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Objective 1. Conduct consumer education and marketing research on organic produce focusing on Alabama. Project scientists organized workshops throughout Alabama to educate consumers on benefits of organic foods. They also conducted market studies and communicated with industry stakeholders and determined best avenues to acquire producer and market intermediary survey participation and developed relationships for further learning. We published quarterly articles relevant to organic growers and consumers. Forums were also organized to share and listen to concerns of organic growers and consumers in Alabama. We conducted Organic Foods Forums on Alabama universities campuses and in major cities of the state. In each even, a panel of experts presented their knowledge briefly and then the audience was invited to engage in through questioning and commenting. This model has shown illicit high response and engagement from learners. As a part of these consumer education events, the audience was invited to experience organic cuisine through a fully cooked, 100% organic meal as well as participate in an organic food taste experiment. Pre-test, post-tests, and surveys were administered at the events. Together with our partners we developed a comprehensive events calendar featuring more than 220 events from a wide variety of partner organizations and farms, including food-related social events and food festivals, on-farm field days, workshops, and conferences. Upcoming events were featured in monthly e-blasts and in quarterly print newsletter, which reach roughly 3000 around the state and beyond. Farm-to-fork picnics were held in Huntsville. Surveys via online platform and in-person at the Alabama Fruit and Vegetable Growers Association annual conferences. Each year, roughly 50 grower responses were collected across all survey collection methods. We conducted preliminary analysis of grower data, and published results in Alabama Farmer's Cooperative magazine. Some major findings were: Major barriers to certifying organic among the respondents involved the cost of certification, both the initial and maintenance costs and paperwork involved with the certification and record keeping process. Producers indicated that insect, weed, and disease control were more challenging in organic production than in conventional. Producers indicated that high costs of labor and organic inputs, and finding consistent buyers and price premiums are all challenges with organic production. We finalized in Alabama with Qualtrics and nat various industry conferences and determined market intermediaries that constitute logistic barriers to Southeast organic markets. Objective 2. Provide organic growers with site specific recommendations on selected vegetable crops. Tuskegee University completed the Organic Farm Certification process with Quality Certification Services - Project staff and scientists underwent a complete organic farm inspection process and officially applied and obtained organic status. Based on field trials conducted at three research stations throughout the Southeast region (North Carolina, Alabama, and Mississippi), we provided site specific recommendations on vegetable crop varieties and OMRI approved pesticides. Major

findings have been published in journals and extension factsheets. On-farm field trials were conducted in Tennessee (McMinnville, Nashville, College Grove, Memphis, and Stanton), in Georgia (Monroe and Rincon), in Alabama (Roanoke, Tuskegee, Moundville, Hampton Cove, Tuscaloosa, Cuba, Fairhope, Shorter, and Ariton), in North Carolina (Calabash, Leicester, Monroe, Penrose, Snow Hill, and Willard), in South Carolina (Johns Island and Wares Shoals), and in Mississippi (Tupelo, Starkville, Flora, Houston, and Philidelphia) on three main vegetable crop varieties of tomato, sweet potato, squash, and southern pea and on several varieties of secondary vegetable crops. Average number of trials in each category is shown in Tables below. Table 1. Average number of on-farm trials conducted on main (mandated by project) vegetable crops each year. Main Study Crop Number of On-farm Trials in Study Squash 26 Tomato 23 Southern Pea 20 Sweet Potato 19 Table 1. Number of on-farm trials conducted on secondary (challenging vegetable crops at specific farms) vegetable crops each year. CROP NUMBER OF ON-FARM TRIALS IN STUDY Squash 17 Tomato 14 Southern Pea 10 Sweet Potato 10 Peppers 3 Beet 2 Carrots 2 Cucumber 2 Kale 2 Lettuce 2 Watermelon 2 Beans 1 Canteloupe 1 Cauliflower 1 Edamame 1 Leeks 1 Okra 1 Sweet Corn 1 White Potato 1 Number of On-farm Trials by Crop Type Note that each crop trial includes two varieties, so the actual number of trials is double the crop number. Objective 3. Develop a participatory extension and evaluation program to support organic food systems. A Food & Farm Forum was organized and attended by adults and youth. The adult attendees enjoyed a rich program of 28 concurrent sessions, with an emphasis on farmer-led and hands-on sessions on organic production and consumption. The Youth Forum comprised 13 sessions on everything from greywater to seed saving, to hog butchery and vegan cooking, to equity and adultism. We organized four Tailgate Trainings \-- peer-to-peer on-farm trainings conducted by producers for producers. Each training was structured to meet the particular needs, questions, and circumstances of those in attendance. Trainings occurred in conjunction with a social component. We conducted organic research trials, train extension, and served as extension agents for new crops and organics. Our project provided a test site at the Mountain Research Station to help fulfill education opportunities for regional organic growers. Researchers and extension agents field inquired and hosted field days with hands-on learning opportunities throughout growing seasons and over 50 participants every year viewed the on station field trials for field days. Our project contributed to the training of state research station staff and summer student workers from participating institutions. Opportunities for organic production and field maintenance skill building, entomological data collection, and education on the issues and needs of our regions organic producers were ongoing. Also North Carolina and Alabama Cooperative Extension agents received education and opportunities for professional development from our project. We organized at the NCDA Mountain Research Station in North Carolina an Alternative Crops and Organics Field Day that was focused on variety and pesticide trials of our research project. 50 attendees were educated on organic production and pest control, and the project goals. A soil health workshop followed the field tour. A diversity of age groups was present. In addition, the research center served as a destination for Haywood County High School and Elementary Schools throughout the growing seasons. Leftover produce was received by regional gleaners with the St. Andrews society - providing organic food and education to more stakeholders in the regional organic food. Objective 4. Build a database for organic information for the benefits of organic farmers in all regions of the nation. On eOrganic Website, we developed pages on our project for sharing information with growers: <https://eorganic.info/southeast>. We developed Video Resources and Virtual web resources for Training and Engagement. Twelve Lunchboxes and Grower spotlights were also developed at selected project farms Publications Type: Other Status: Published Year Published: 2021 Citation: Sonu Koirala B. K. Franklin Quarcoo, Kokoasse Kpomblekou-A, Desmond Mortley. 2021. Organic Tomato Production in Alabama: Host Preference of the Tomato Hornworm (Manduca quinquemaculata) and Performance of Selected Biopesticides. 2021; 5(1): 10-17 http://www.sciencepublishinggroup.com/j/aje doi: 10.11648/j.aje.20210501.12 ISSN: 2640-0529. K. Kpomblekou-A, M. Schonbeck, A. C. Bovell-Benjamin, and L. Snyder. 2020. Proceedings of the 2020 Organic Agriculture Research Forum. January 23, 2020, Little Rock, AR. https://ofrf.org.reports. Anitha Chitturi, Olufemi S. Ajayi, Franklin Quarcoo, Kokoasse Kpomblekou-A, and Desmond Mortley. 2021. Management of aphids in organic tomato production in Alabama. Alabama Extension Fact sheets at <https://www.tuskegee.edu/extension>. Anitha Chitturi, Olufemi S. Ajayi, Franklin Quarcoo, Kokoasse Kpomblekou-A, and Desmond Mortley. 2021. Management of the tomato hornworm in Organic tomato production in Alabama. Alabama Extension Fact sheets at <https://www.tuskegee.edu/extension>. Anitha Chitturi, Olufemi S. Ajayi, Franklin Quarcoo, Kokoasse Kpomblekou-A, and Desmond Mortley. 2021. Management of stink bugs in organic tomato production in Alabama. Alabama Extension Fact sheets at <https://www.tuskegee.edu/extension>. Anitha Chitturi, Olufemi S. Ajayi, Franklin Quarcoo, Kokoasse Kpomblekou-A, and Desmond Mortley. 2021. Management of Tomato Fruitworm in Organic Tomato Production in Alabama. Alabama Extension Fact sheets at <https://www.tuskegee.edu/extension> Chitturi Anitha, Davis Jeanine, Bloomquist Margaret, Quarcoo Franklin, Kpomblekou-A Kokoasse, Mortley Desmond. 2019. Insect Population Dynamics, Varietal Preference and Performance of Organic Bio-Pesticides. Professional Agricultural Workers Journal: Vol. 7: No. 1, 11. Available at https://tuspubs.tuskegee.edu/pawj/vol7/iss1/11 1. Davis, Keniya and Julian Jones. 2019, Nutritional and Physical Contents of Organic Sweet Potatoes (Ipomoea batatas \L.\ Lam) Treated with Organic Pesticides Goodrich, Brittney, Joel Cuffey, and Kokoasse Kpomblekou-A. 2020. Challenges

and Barriers to Certified Organic Production in Alabama. eOrganic article. Available at <http://eorganic.org/node/34351>. Progress 09/01/19 to 08/31/20 Outputs Target Audience:The audience was organic growers, restaurant managers, extension personnel, and consumers Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals?The project is ending so there will be nothing to report. Impacts What was accomplished under these goals? Nothing was accoumplished because project team members could not traveled due COVID19 travel restrictions imposed by the university personnel.

PROGRESS

2018/09 TO 2019/08 Target Audience:The target audience was organic growers and consumers in the southeast. Changes/Problems:The major challenges encountered relateto: Unpredictability in weather events. Several growers could not plant their crops on time because of hurricanes and/or long rainfall events for example in North and South Carolinas, and in Tennessee. Some growers are not following recommendations made by the project team (row lengths, weeding, irrigation, and harvest procedures). Some growers do not plant their crops although they received their contract money. Some have not fixed their irrigation systems and or have not put fence around their field even though they promise to do so. As a results, deer devastated their crops. Some farmers do not participate in the lunchbox events organized for their benefits. What opportunities for training and professional development has the project provided?A student completed a MS degree using research data obtained on field experiments and an international student worked with the project team as an intern. In addition, ten other students provided research support to the team during summer 2019. A student in agriculture economics conducted a marketing test on organic produce in Alabama and Georgia. A Collaborative Regional Alliance for Farmer Training (CRAFT) Program was developed in May 2019. This effort is slightly a new approach to familiar work \-- peer-to-peer, on-farm, and farmer-led training that includes intentional space for community-building and social support. CRAFT is a model well-established elsewhere, but relatively unestablished in the Deep South. We plan to synthesize feedback from four pre-pilot workshops in 2019, and set the topics, host farms, and dates for the 2020 workshop series. Of the four trainings slated for this fall, we have held one so far - on 8/26 at Walden Farms and Farmacy in Bessemer, focusing on Permaculture. The three remaining events will be: 9/23/19 at Hepzibah Farms in Talladega - Cut Flower Production 10/13/19 at Jones Valley Teaching Farm in Birmingham - Perennial Fruit Production 11/17/19 at BDA Farm in Uniontown - No-Till Production. Over 50 participants viewed the on-station bio pesticide field trials during for a field day on July 18, 2019. This project contributed to training of state research station staff and summer student workers from participating institutions. Opportunities for organic production and field maintenance skill building, entomological data collection, and education on the issues and needs of our regions organic producers were ongoing. North Carolinan Cooperative Extension agents also received education and opportunities for professional development from this project. At the Mountain Research Station, an event was held on July 18thcalled the Alternative Crops and Organics Field Day. Part of this event focused entirely on the variety and pesticide trials of this research project. Over 50 attendees were educated on organic production and pest control. A soil health workshop followed the field tour. A diversity of age groups were present. In addition, the research center served as a destination for Haywood County High School and Elementary Schools throughout the season. Leftover produce was received by regional gleaners with the St. Andrews society - providing organic food and education to more stakeholders in the regional organic food system. Extension Service.The project team provided extension services and site-specific recommendations to our organic grower partners in AL, GA, NC, MS, SC, and TN. Each grower partner in Alabama, Tennessee, Georgia, North Carolina, South Carolina and Mississippi was visited during the 2019 growing season in order to confirm that planting and site-specific recommendations provided were followed. The Tuskegee team, visited farms in Alabama, Georgia, and Tennessee. In all, 16 of the 18 farms were visited this year. Each farm was evaluated by a project Entomologist and provided site-specific recommendations as needed. Detailed logs were completed for each farm visit that included photo documentation. The farm visited were located in Tennessee: McMinnville, Nashville Memphis, College Grove, and Stanton, in Georgia: Monroe, Rincon, and Rincon, in Alabama: Roanoke, Tuskegee, Moundville, Hampton Cove, Tuscaloosa, Cuba, Fairhope, Shorter, and Ariton, in North Carolina: Calabash, Leicester, Monroe, Penrose, Snow Hill, Willard, and Wares Shoals, in South Carolina: Johns Island, in Mississippi: Tupelo, Starkville, Flora, Houston, and Philadelphia. How have the results been disseminated to communities of interest?A comprehensive event-calendarfeaturing events from a wide variety of partner organizations and farms, including food-related social events and food festivals, to on-farm field days, workshops, and conferences is available athttp://asanonline.org/events. A running preview of upcoming events is featured in monthly e-blasts and in quarterly print newsletter, which reach roughly 3000 around the state and beyond. On July 14, we held a farm-to-fork picnic fundraiser in Birmingham and in Huntsville for the first time. We also conducted a producer survey via online platform and in-person at the Alabama Fruit and Vegetable Growers Association annual conference in November 2018. Roughly 50 grower responses across all survey collection

methods. Conducted preliminary analysis of grower data, and published results in Alabama Farmer\'s Cooperative magazine. Some major findings from the survey were: 1) Major barriers to certifying organic among the respondents involved the cost of certification, both the initial and maintenance costs and paperwork involved with the certification and record keeping process; 2) Producers indicated that insect, weed, and disease control were more challenging in organic production than in conventional; 3) Producers indicated that high costs of labor and organic inputs, and finding consistent buyers and price premiums are all challenges with organic production. In addition, we conducted two Organic Foods Forums on October 25, 2018 on the campus of Tuskegee University (well over 100 participants in attendance) and on February 22, 2018 at the Farmer\'s Conference in Montgomery, Alabama. As part of these consumer education events, the audience was invited to experience organic cuisine through a fully cooked, 100% organic meal as well as participate in an organic food taste experiment. Pre-test, post-tests, and surveys were administered at the events. We continue to develop resources for the eOrganic resource bank. What do you plan to do during the next reporting period to accomplish the goals?We will conduct social events aimed at connecting producers, food service industry professionals, and consumers. We will finalize market research surveys and present findings; we will conduct organic food forums at three universities in Alabama; will produce short videos to highlight organic/transitioning growers in Alabama; local media in participating growers\' communities will be informed of the project and be encouraged to cover it at the local level. Press releases will be developed and dispersed, interviews on local (Alabama) public radio and television stations will be conducted with project staff. One or two cooking events are planned andwill berecorded. During the growing season for the coming year, the project team will continue to make field visits to participating farms in order to address issues specific to the growing site. Each grower will be provided a report, a set of recommendations, and a follow up. The project team will continue to conduct on-farm research trials at the three experiment stations taking into consideration lessons learned from the previous years in order to continue the development of site-specific recommendations. The Lunchbox Meetings will continue where institutional partners will make themselves available to interact with grower partners to address critical topics. In addition, the growers will facilitate some of the meetings as a time to share knowledge, wisdom and feedback from the project. We will continue to process, organize and analyze research data. Will continue the development of eOrganic website for sharing information with growers. We will continue developing video and virtual web resources in order to make resources available for the eOrganic webpage.

2016/09 TO 2017/08 Target Audience:Our efforts this first year were focused on informing Tuskegee University faculty, student, consumers and educators about the need to strengthen organic production activities in the southeast. Changes/Problems:Farmer recruitment to host the on-farm field trials is challenging because not manyorganic farmersin the southeast are willing to collaborate.But finally, we have them onboard. What opportunities for training and professional development has the project provided?Not yet; organic farmers\' trainings and professional development opportunities will be offered by the project team next year. How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals?We planned on conducting consumer education workshops throughout Alabama, completing the marketing survey in Alabama, hiring project personnel, and starting on farm trials in the southeast.

IMPACT

2018/09 TO 2019/08 What was accomplished under these goals? Objective 1. Conduct consumer education and marketing research on organic produce focusing on Alabama We continued communication with industry stakeholders to determine best avenues to acquire producer and market intermediary survey participation. An electronic publication is released quarterly including 4 times during this reporting period.An overwhelming portion of the newsletter is relevant to organic growers and organic consumers. All the publications are archived and available athttp://asanonline.org/archived-newsletters. Objective 2. Provide organic growers with site specific recommendations on selected vegetable crops. Tuskegee University now has a 20-acre certified organic research plot located on the George Washington Carver Agriculture Experiment Station at Tuskegee University. At the three research stations (Alabama, Mississippi, and North Carolina), three bio pesticides were investigated.Azadirachtin, Pyrethrin, and Spinosad were tested on three varieties each of summer squash (Gentry, Spineless Beauty, and Zephyr) and southern pea (Pinkeye Purple Hull, Queen Anne, and Mississippi Silver). In addition to those two crops, Tuskegee University tested the bio pesticides on three varieties of tomato (Mountain Magic, Celebrity, and Rocky Top); also different rates of a certified organic fertilizer were tested on yields ofthree varieties of sweet potatoes (Garnet, Covington, Orleans). Sticky card were placed to monitor insect thresholds and when treshholder was achieved, we followed-up with application of each pesticides every week. Monitoring the fields with sticky cards and scouting every week and applying organic pesticide based on insect

population thresholds. At Tuskegee University Experiment Station, this research resulted in a thesis entitled: Performance of Selected Biopesticides against Major Insect Pests in the Organic Production of Summer squash and Southern pea in Alabama. Major insect pests recorded on the tomatoes include: Tomato hornworm, tomato fruit worm, armyworm, thrips, aphids, brown marmorated stink bug, and green stink bug. Armyworms, brown marmorated bugs, hornworms, and tomato fruit worms attained economic threshold levels and were sprayed with biopesticides to reduce their populations. Data for the other major listed insects and some minor insect pests are currently being analyzed. Insect population data will be analyzed to determine possible differences in the population of major insects recorded on the three varieties of tomatoes. Major insect pests recorded on summer squash include the squash bug, cucumber beetle, leaf-footed bug, brown marmorated stink bug, and green stink bugs. All these pests attained their respective economic threshold population levels and were sprayed with the candidate biopesticides.Analysis of the 2019 data is ongoing. No cow pea pods were harvested because of insects that devasted the crop. Several pests were recorded and the bio pesticides were not not effective. Analysis of the 2019 data is ongoing and will determine next step measures to take. In Mississippi, from the weekly visual scouting, the key pests observed in southern pea included leafhoppers, stinkbugs and leaf footed bugs. Leafhoppers were observed as a major pest throughout the cropping season beginning mid-June to mid-July. Leaf footed bugs and grasshoppers were observed during the harvest season beginning early August and continued until the end of cropping season. Four harvests were conducted between August 6 and August 23. At the North Carolina State University MountainResearch Center, green peach aphids (Myzus persicae), cucumber beetles, pickle worms, powdery mildew spores,leafhoppers, and amaranth flea beetles were observed throughout the field in the beginning of August through harvest. Cucumber mosaic virus was confirmed by NCSU\'s Plant Disease and Insect Lab on August 19, 2019 though was not widespread and only on \< 2% of plants on the field.Insect pest population in S. pea were monitored every week with yellow sticky traps;the key pests observed in southern pea include leafhoppers, flea beetles and cucumber beetles (spotted and striped). Leafhoppers and flea beetles were observed as a major pest beginning late July and continued throughout the cropping season until end of August. Cucumber beetles were observed in very low numbers all through the cropping season. Objective 3. Develop a participatory extension and evaluation program to support organic food systems. A Food & Farm Forum was attended by 168 people, including 132 adults and 23 youth. The adult attendees enjoyed a rich program of 28 concurrent sessions, with an emphasis on farmer-led and hands-on sessions. An overwhelming portion of the featured topics/sessions related to organic production and/or consumption in some way. A first Youth Food & Farm Forum planned by a Youth Forum Coordinator along with a 6-member Youth Council from across Alabama was held in Alabama. The Youth Forum comprised 13 sessions on everything from greywater to seed saving, to hog butchery and vegan cooking, to equity and adultism. The inaugural Youth Forum was attended by 23 youth ages 13-23, representing all parts of Alabama. In North Carolina, we continue to host organic research trials, train extension personnel, and serve as extension agents for new crops and organics. This project provides a test site at the Mountain Research Station to help fulfill education opportunities for regional organic growers. Researchers and extension agents field inquires and host field days with hands on learning opportunities throughout the season. In March 2019, the project team hosted lunch box series #9: 2019 New Grower Data Log Review and Planting Discussion. Recording of the discussion was uploaded to site April 2nd, 2019. Objective 4. Build a database for organic information for the benefits of organic farmers in all regions of the nation. The project shares information with growers on eOrganic website: https://eorganic.info/southeast. We also develop Video Resources for Training and Engagement, virtual web resources for the eOrganic webpage. The Lunchbox #10 - Pest Overview in Organic Systems: Spotlight on Tomato is posted on https://youtu.be/CaZsFdI0Zrw. Lunchbox #11 - Pest Issues - Spotlight on Squash is posted on https://youtu.be/-dVtAYBwbPM. Lunchbox #12 - Pest Issues - Spotlight on Southern Pea is posted on https://youtu.be/uPhcljF3TrY. Pest Management of Tomato Hornworm is posted on: https://youtu.be/-4mbCVrktWw and Don\'t kill every single pest! Integrated Pest Management Tips is posted on: https://youtu.be/968lDHRfEmk. **PUBLICATIONS (not previously reported):** 2018/09 TO 2019/08 Type: Journal Articles Status: Published Year Published: 2019 Citation: Chitturi Anitha, Davis Jeanine, Bloomquist Margaret, Quarcoo Franklin, Kpomblekou-A Kokoasse, Mortley Desmond. 2019.Insect Population Dynamics, Varietal Preference and Performance of Organic Bio-Pesticides. Professional Agricultural Workers Journal: Vol. 7: No. 1, 11. https://tuspubs.tuskegee.edu/pawj/vol7/iss1/11

2016/09 TO 2017/08 What was accomplished under these goals? Mixed cover crops (legumes and grasses) were planted in October 2016 in preparation for the pilot study to be conducted at Tuskegee University in spring 2017. A project kickoff meeting was organized at Tuskegee University from February 26 through the 28, 2017 with participation of all major project collaborators. Twenty nine project collaborators, scientists, advisory board members, and students participated in the two-day meeting. A marketing survey is being designed by Auburn University on organic marketing research with focus on Alabama. Additional organic growers were hired to host organic farming trials for the next coming three years. A website is being designed for the project. **PUBLICATIONS (not previously reported):** 2016/09 TO 2017/08 No publications reported this period. ** **

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Multi-regional Risk Analysis of Farm Manure Use: Balancing Soil Health and Food Safety for Organic Fresh Produce Production

Accession No.	1010610
Project No.	CALV-12117374
Agency	NIFA CALV\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2016-51300-25724
Proposal No.	2016-04422
Start Date	01 SEP 2016
Term Date	31 AUG 2020
Grant Amount	$1,999,848
Grant Year	2016
Investigator(s)	De Andrade E Pires, A. F.

NON-TECHNICAL SUMMARY

Certified organic producers rely on manure-based soil amendments for crop nutrients and to maintain soil health. However, use of untreated animal manure in fresh produce cropping systems may introduce foodborne pathogens and increase the risk of foodborne illness for consumers. Few scientific studies documenting pathogen die-off in organic systems are available to support specific wait periods between manure application and crop harvest. The proposed project uses an integrated research-extension risk-based approach to address an urgent and critical need to assess current manure use by organic growers and evaluate pathogen survival time relative to soil health status. Specific aims include: 1) Risk analysis of on-farm practices associated with persistence of pathogens on organic farms using manure-based soil amendments in diverse cropping systems; 2) Determine the relationship between soil health and pathogen survival in organically managed produce fields amended with raw animal manure; 3) Develop a comprehensive on-line and in-person (mixed model) outreach program to provide technical and systems-based produce food safety training for the organic farming community. The long-term goal is to improve the microbial food safety of fresh organic produce (e.g., leafy greens, tomatoes, root vegetables) grown in soils amended with raw manure. The overall objective is to develop a customized risk-assessment based on good agriculture practices, rigorous microbial testing, self-assessment of soil health, and environmental factors. The outcomes of this project will benefit organic farmers and consumers by providing science-based strategies to maintain the value of raw manure soil amendments while limiting food safety risks.

OBJECTIVES

The long long-term goal of this project is to improve the microbial food safety of fresh organic produce grown in soils amended with raw manure and typically eaten raw (e.g., leafy greens, tomatoes, root vegetables). The overall objective is to develop a customized risk-assessment based on good agricultural practices, rigorous microbial testing, self-assessment of soil health, economic impacts (cost/benefit) and environmental factors to maintain the value of raw manure soil amendments while limiting food safety risks. The specific objectives are: 1) Assessment of on-farm practices, environmental factors and soil health associated with the persistence of pathogens among organic farms using raw manure as a soil amendment, in the diverse conditions of organic farming in three organic regions of the U.S.; 2) Determine the relationship between soil health and pathogen survival in organically grown fresh produce fields amended with raw animal manure in multiple U.S. regions; 3) Develop an outreach program targeting organic producers using biological soil amendments of animal origin. We

will accomplish these goals and objectives by increasing the understanding of persistence and survival of foodborne pathogens, their ecology, and relationship to soil health, which will be used to develop targeted mitigation strategies for risk management in organic produce environments (e.g., customized on-farm food safety approaches). This project will also develop a nationwide and regional outreach program available to organic growers to reduce the risk of introduction/persistence of pathogens in fresh produce production and preserve the benefit of raw manure use in organic and sustainable agriculture.

APPROACH

The overall goal of the Activity 1 is to develop a customized food safety risk-analysis for contamination of produce in organic agriculture. A longitudinal study design will be conducted over two-years to capture two crop cycles and time-variable factors in three regions: West, Midwest and East. A total of 27 certified organic farms \NOP certified organic; produce at least one of the following fresh crops: leafy greens (e.g., lettuce, spinach), root vegetables (e.g., carrots, radish) and fruits (e.g., tomatoes, cantaloupe or melons); use raw or untreated manure of dairy cattle, horse or poultry sources in produce fields\ will be included in the study. Repeated sampling of composite manure, composite soil, water and produce will be conducted in order to assess the prevalence and survival of foodborne pathogens (Salmonella, STEC, non-STEC, and L. monocytogenes) and indicators of contamination (E. coli die-off). Soil health will be evaluated (microbiome analysis, general soil chemistry and soil health self- assessment and scoring). Management and farm practices (e.g., demographics, size, irrigation, crops, soil amendments, soil health, etc.) and environmental factors (meteorological and landscape data) will be recorded during the study period. Multilevel logistic regression and zero-inflated multilevel effect negative binomial models conducted to determine the association between on-farm management factors, manure factors, soil factors (health and level of contamination), environmental factors and landscape on fresh produce in each of the following outcomes of interest: 1) the prevalence of pathogens (Salmonella, STEC and L. monocytogenes) and 2) levels of microbial contamination indicators (i.e., generic Escherichia coli survival or die-off rate) in fresh produce.A customized self-risk assessment will be displayed and mapped graphically and in tables within the \"MU-safe\" dedicated site (within the web-based platform referred to as Disease BioPortal ® and a user-friendly mobile application or \"App\"). The self-risk assessment will account for multiple factors (e.g., on-farm management factors, soil health, survival of pathogens environmental and landscape factors) that are significantly associated with the persistence and prevalence of pathogens in fresh produce crops. Finally a cost effectiveness and economic analysis will be conducted to evaluate different strategies employed based on soil type, proximity to livestock production facilities, climate, specific crop, availability of alternatives, and costs.The Activity 2 will take place in 3 certified organic centers (West, Midwest and East). The overall goal of this activity is to determine adequate wait times between manure application and crop harvest on organic farms. Experimental field trials (randomized complete block) will be conducted to determine appropriate application intervals for biological soil amendments of animal origin on organic farms. The field trials will include rpeated testing of soil plots and manure (dairy manure, poultry litter and horse manure) as well as at plant harvest (spinach, radish and tomatoes) to assess initial presence and die-off of pathogens and contamination indicators (E. coli (gEC). Soil microbial community profiling and competitive inhibition assay will be assessed under different manure treatments. Analysis of variance, multivariate analysis will be used to evaluate the treatment effects on pathogen survival and die-offs.The overall goal of the Activity 3 is to develop a nationwide and regional outreach program available to organic growers to reduce the risk of introduction/persistence of pathogens in fresh produce production and preserve the benefit of raw manure use in organic and sustainable agriculture. Relevant farmer-focused outreach and extension efforts aimed directly at organic farmers through the development and presentation of a webinar, continuing education modules and fact sheets for organic growers. The outreach plan is multi-tiered to ensure constant stakeholder engagement (project advisory committee and stakeholder groups) and effective results dissemination. It will incorporate input from the during the entire course of the outreach process. The outreach will be evaluated using both quantitative and qualitative metrics. **Progress** 09/01/16 to 08/31/21 **Outputs** Target Audience:The target audiences reached include various stakeholders in organic agriculture and produce food safety, including organic farmers, researchers, extension specialists and agents, policy makers, educators, and experts and industry working in organic agriculture. They were reached as part of the conferences, webinars and informal education activities delivered through presentations at national and international meetings and conferences. In particular, many stakeholders were exposed to our research findings at the: Agroecology & Organic Systems Workgroup UC ANR Meeting (online webinar), California, December 1, 2020 MOSES Organic Farm Conference 2021 Feb. 22-27, 2021-Virtual Meeting. Online Webinar, February 24, 2021 California Farm Food Safety E-Learning Series; UC Davis Food Safety. Online Webinar, April 7, 2021 Managing Soil Amendments for Food Safety and Soil Health. Workshop Series. The Organic Center (TOC). Online Webinar, July 15, 2021 Science Based Composting Practices. Workshop Series. The Organic Center (TOC). Online Webinar, July 23, 2021 Produce Safety Alliance (PSA) Educator's Call webinar series, Online Webinar, August 16, 2021 Produce Safety Rule: Regulation and Good Agricultural Practices, Inter-American

Institute for Cooperation on Agriculture (IICA), July 27, 2021 United States Composting Council's annual meeting, January 26-27, 2021 The Organic Center developed a web portal where a description of the project, updates, and information has been posted. We also launched and maintain a social media campaign surrounding the research via The Organic Center, Organic Trade Association Facebook and Twitter accounts, and UC ANR webpages. Changes/Problems:The cost-benefit study was not conducted because no budget was allocated for this sub-objective and we were unable to identify a new collaborator. What opportunities for training and professional development has the project provided?The project provided support for graduate/post-doctoral (1PhD student, 1 post-doctoral researcher, 1 master student, 5 undergraduate), thus helping to build capacity for future professionals in microbiology, epidemiology and food safety. How have the results been disseminated to communities of interest?We are communicating our accomplishments to communities of interest using a variety of techniques. We pushed out a press release about the project, which can be found on 214 websites, with a potential total audience of 11,804,269 unique visitors per day.The total potential audience from tweets of the press release is 30,976 followers. Additionally, we are communicating with the public through the website, which was redesigned in 2020 to include a short summary of the project, a detailed description of the project, information about the research team, and a list of presentations and publications that have come out of the project. The website also includes a News & Updates page, which includes updates with pictures from the field, announcements about upcoming events, and extension material. We have also leveraged the project outreach with The Organic Center's Google Ad Words Grant, which provides up to \$40,000 of funding per month for Google Ad Words. Over the 4 years of the project, this campaign has generated a total of over a million clicks and 10 million ad views. We are using social media to ensure that we reach a wide variety of stakeholders via The Organic Center and Organic Trade Association social media pages. The combined Twitter following for these organizations is 70,200 and the Facebook following is 149,412. The project has also been communicated through in-person meetings with industry and farmer partners. For example, it was featured at the Organic Confluences Conference, which focuses on collaborative solutions to organic sector challenges. Finally, the project has been publicized in several Newsletters, including the Organic Center Scoop, which goes out to 23,689 individuals, and the Organic Trade Association Newsflash, which goes out to 3,500 subscribers. The project was also publicized in the Organic Report, a magazine with a readership of over 21,000. The Organic Center has also been ensuring the project outcomes reach industry members, including the Organic Trade Association's Produce Safety Council. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? Activity 1: Data from a longitudinal, multi-regional study was conducted on nineteen USDA-NOP-certified farms in 4 USA regions (9 CA, 4 ME, 5 MN and, 1 MD) was compiled and analyzed. Findings related to this project have been published in Front. Sustain. Food Syst. (Ramos et al, 2021). Farm management practices, environmental and weather factors were associated with persistence of non-O1257 STEC and Listeria monocytogenes in organically managed soils amended with untreated manure on USDA-NOP certified organic farms in 4 regions in the US (manuscript submission pending). This study provides science-based information to identify potential risk factors influencing foodborne pathogen persistence in pre-harvest produce production environments for soils amended with raw manure on organic production systems. These findings are of particular importance for the organic industry, as many certified organic producers and small-scale farms rely on animal-based soil amendments to improve soil fertility and quality. We have created an interactive, user-friendly dashboard for individual farm risk assessment, in collaboration with CADMS, UC Davis. Activity 2: Preliminary statistical analyses were conducted for the CA and MD field trials. A randomized complete block study was conducted on NOP-certified plots during 2017-2018 in CA, MN and MD. Survival of generic E. coli rif-R (EC) on soil, tomatoes, radish/carrots and spinach was determined over 90-120 days for dairy manure (DM), horse manure (HM), poultry litter (PL), and unamended (UnA) plots. The long-term survival of E. coli in manure-amended soil and transfer to spinach and carrots under certified organic cultivation was observed, similar to findings in the previous crop year; however, transfer to tomatoes was not previously documented. Our findings suggest longer USDA-NOP (>120 days) wait periods or composting may be needed to protect organic vegetable crops from fecal pathogen contamination via raw animal manure-amendment. Activity 3: The project website (<https://www.organic-center.org/site/multi-regional-risk-analysis-farm-manure-use>) includes pages dedicated to describing the project, highlighting the research team, and showcasing publications and presentations that have come out of the project. We also have a news page which allows us to provide updates, photos, and videos about the project, as well as announce upcoming talks and share extension material. To date, we have posted 2 videos and 43 photos. The Organic Center, UC Davis, and Produce Safety Alliance personnel collaborated to deliver two webinars, \"Managing Soil Amendments for Food Safety and Soil Health\" and \"Science-based Composting Practices\" (July 15 and 22, 2021). Intended for an audience of growers and industry members, the two-part series outlined benefits and risk reduction practices when using manure, compost, and other BSAAO used on produce farms. The first webinar introduced how the use of BSAAO improves soil health. Research on pathogen survival in BSAAO-amended soils was presented, as well as how growers can minimize the risks of using untreated soil amendments through proper application, storage, handling, and recordkeeping practices. The second presentation highlighted science-based

composting practices used to minimize microbial food safety risks. The webinars introduced common practices and BSAAO such as rotational grazing, vermicompost, and compost tea, and had experts responding to participant questions throughout the presentations. The first webinar entitled \"Managing Soil Amendments for Food Safety and Soil Health,\" had 333 live registrants, 96 on-demand view webinar, 429 total. The second webinar presented, entitled \"Science Based Composting Practices,\" had 245 live registrants, and 20 people register for on-demand viewing of the webinar, 265 total). Both of these webinars are viewable on the project webpage. Webinar participants were invited to fill out a survey to evaluate the presentations. Evaluation respondents felt more confident in their ability to assess risks on their farm. When asked what changes may be made to farm practices after viewing the webinars, participants mentioned better recordkeeping, improved monitoring during treatment, increased application of compost on the farm, and opting to research the production of compost in-house rather than buying from a supplier. Evaluation results are being used to inform the development of teaching notes for the two modules before they are publicly posted to the PSA website. The PSA maintains several social media platforms, which have been used to highlight updates on this project, including these two webinars. The PSA's Facebook, Instagram, Twitter, and YouTube accounts reach 2,318, 349, 555, and 503 followers, respectively Two educational outreach modules have been developed to help reach a broad array of stakeholders: \"Science-based composting practices\" and \"Guidelines for manure use in produce production to enhance soil health\". These modules were presented as webinars to a diverse audience, including through The Organic Center's webinar series. Slides from the two educational modules were presented on July 27, 2021 for the \"Produce Safety Rule: Regulation and Good Agricultural Practices\" Spanish-language webinar series hosted by the Inter-American Institute for Cooperation on Agriculture. The hour-long presentation attracted 251 participants from various Latin American countries. A one-hour presentation on the FSMA Produce Safety Rule and its impact on the composting industry was delivered at the United States Composting Council's annual meeting (January 26-27, 2021). In a collaboration between PSA, Local Food Safety Collaborative, and US Food and Drug Administration, a portion of the webinar content was informed by the educational modules. The audience of sixty participants included compost companies, state regulatory agencies, and compost industry representatives. Pires (UC Davis), and Clements (Produce Safety Alliance), presented slides from the two educational modules as part of a UC Davis e-learning series on BSAAO. The two webinars, hosted April 7 and April 14, 2021, presented risks associated with BSAAO, including manure and compost issues; an overview of the FSMA Produce Safety Rule and BSAAO; and application intervals associated with treated and untreated BSAAO. The webinars were attended by 54 and 60 participants, respectively. This project was highlighted for produce safety educators via the monthly PSA Educator's Call webinar series (August 16, 2021). This webinar, \"Managing Food Safety Risks While Using Soil Amendments: An Overview of New Resources\", had Pires (UC Davis) and Bihn (PSA) review current research and the two supplemental modules being developed. This webinar attracted 60 live participants and an additional 91 views of the recording. A factsheet on regulatory documentation requirements for commercial soil amendment suppliers, published in September 2019, continues to be promoted to the soil amendment industry, growers, and educators. Since being published, the factsheet has been accessed 631 times on the PSA website, and the accompanying editable Certificate of Conformance (CoC) template was accessed 316 times. The Spanish translation of the factsheet and CoC have been accessed 268 and 168 times, respectively. Demand for this content was highlighted in published grower needs assessments. Two educational outreach modules are being finalized to publish on the PSA website for produce safety educators and industry members to access. The finalized modules will be translated and posted on the PSA's Spanish-language website to support Spanish-speaking audiences. The two modules are currently being revised based on input from The Organic Center webinar participants, solicited via Qualtrics surveys. **Publications** - Type: Journal Articles Status: Published Year Published: 2021 Citation: De Melo Ramos T, Jay-Russell M, Millner PD, Baron JN, Stover J, Pagliari P, Hutchinson M\...\... Pires AFA Survival and Persistence of Foodborne Pathogens in Manure-Amended Soils and Prevalence on Fresh Produce in Certified Organic Farms: A Multi-Regional Baseline Analysis. Front. Sustain. Food Syst. 5:674767. doi: 10.3389/fsufs.2021.674767 <https://doi.org/10.3389/fsufs.2021.674767>. - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Kenney A, Hashem F, Pires A, Jay-Russell M, Millner P, Collick, A. 2020. Precipitation and soil moisture effects on survival and transfer of Escherichia coli to fresh produce in manure-amended certified organic, (P3-74) 2020 Annual IAFP Meeting, Virtual Meeting, October 26-28, 2020. (Poster) - Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: Kenney A., F. Hashem, P. Millner, and A. Pires (2022). Transfer of Escherichia coli from Manured Certified Organic Soils to Tomatoes, Radish, and Spinach on the Eastern Shore of Maryland. The 1890 Association of Research Directors (ARD) Research Symposium, Atlanta Marriott Marquis, Atlanta, GA, April 2 - 5, 2022. (Accepted) - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Symposium: Balancing Food Safety and Soil Health through the Use of Biological Soil Amendments Symposium. IAFP 2021. Annual Meeting, July 18-21, Phoenix, Arizona (3 Oral Presentations/ Webinar). - Type: Other Status: Published Year Published: 2020 Citation: Foodborne pathogen dynamics in alternative agricultural & organic systems (webinar). Agroecology & Organic Systems Workgroup UC ANR, California, December 1, 2020 - Type:

Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Use of BSAAO in organic fresh produce production (Webinar), Workshop:\"Building Soil Health and Suppressing Pathogens in Organic Systems\", MOSES Organic Farm Conference 2021, February 24, 2021 Feb. 22-27, 2021-Virtual Meeting - Type: Other Status: Published Year Published: 2021 Citation: Overview of biological soil amendments of animal origin (BSAAO) and the Food Safety Modernization Act Produce Safety Rule (PSR) & Compost(Webinar). Biological Soil Amendments of Animal Origin: California Farm Food Safety E-Learning Series; UC Davis Food Safety Online Webinar, April 7 and April 14, 2021. \2 hours each, 54 and 60 participants, respectively\ URL: https://ucfoodsafety.ucdavis.edu/training/California-Farm-Food-Safety-E-learning-Series - Type: Other Status: Published Year Published: 2021 Citation: \"Managing Soil Amendments for Food Safety and Soil Health\". Workshop Series. The Organic Center (TOC). Online Webinar, July 15, 2021 \333 live registrants, and 96 people register for on-demand viewing of the webinar, for a total of 429 registrants\. https://www.organic-center.org/publications-presentations - Type: Other Status: Published Year Published: 2021 Citation: \"Science Based Composting Practices\". Workshop Series. The Organic Center (TOC). Online Webinar, July 22, 2021. \245 live registrants, and 20 people register for on-demand viewing of the webinar, for a total of 265 registrants\ URL: https://www.organic-center.org/publications-presentations - Type: Websites Status: Published Year Published: 2021 Citation: Website: https://www.organic-center.org/site/multi-regional-risk-analysis-farm-manure-use - Type: Other Status: Published Year Published: 2021 Citation: Produce Safety Rule: Regulation and Good Agricultural PracticesSpanish-language webinar. the Inter-American Institute for Cooperation on Agriculture (IICA). July 27, 2021 \1 hour-long presentation attracted 251 participants from various Latin American countries\. - Type: Other Status: Published Year Published: 2021 Citation: The FSMA Produce Safety Rule and its impact on the composting industry, The United States Composting Councils annual meeting. January 26-27, 2021

PROGRESS

2019/09 TO 2020/08 Target Audience:The target audiences reached include various stakeholders in organic agriculture and produce food safety, including organic farmers, researchers, extension specialists, extension agents, policy makers, experts and industry working in organic agriculture. They were reached as part of the conferences, workshops and informal education activities (field days, one -to-one meetings with farmers) delivered through presentations at national and international meetings and conferences. To reach our target audience the Organic Center disseminated a press release to publicize the planned research. The Organic Center also developed a web portal where a description of the project, updates, and information has been posted. We also launched and maintain a social media campaign surrounding the research via The Organic Center and Organic Trade Association Facebook and Twitter accounts, A unique Twitter account was developed specifically for this project as well. The combined reach of our organizations\' social media pages is followed by over 149,412 individuals onFacebook, and over 70,200 followers onTwitter. The Produce Safety Alliance also maintains several social media platforms, which have been used to highlight updates on this project, including stakeholder presentations and resource updates. The Produce Safety Alliance\'s Facebook, Instagram, Twitter, and YouTube accounts reach 2,091 (Facebook) 277, 506 (Twitter), and 286 (YouTube) followers, respectively. Changes/Problems:The research team is working to identify a new economist to collaborate in this project. Due to the Covid19, the microbial population analysis was delayed, but is expected to be completed during this year, depending on restrictions of lab working in each institution. What opportunities for training and professional development has the project provided?The project provided support for graduate/post-doctoral and undergraduate research, thus helping to build capacity for future professionals in microbiology, epidemiology and food safety. Dr. Pires mentored one PhD student, 1 junior specialist and 3 undergraduate students at UC Davis. A master student (co-mentored by Drs. Hashem, Millner, and Pires) graduated from UMES. How have the results been disseminated to communities of interest?Additionally, we are communicating with the public through a website, which was redesigned in 2020 to include a short summary of the project, a detailed description of the project, information about the research team, and a list of presentations and publications that have come out of the project. The website also includes a News & Updates page, which includes updates with pictures from the field, announcements about upcoming events, and extension material. We have also leveraged the project outreach with the Organic Center\'s Google Ad Words Grant, which provides up to \$40,000 of funding per month for Google Ad Words. This campaign has generated a total of 275,027 clicks and 2,674,981 ad views over the last year. We are using social media to ensure that we reach a wide variety of stakeholders via the Organic Center and Organic Trade Association social media pages. The combined Twitter following for these organizations is 70,200 and the Facebook following is 149,412. The project has also been communicated through in-person meetings with industry and farmer partners. For example, it was featured at the Organic Confluences Conference, which focuses on collaborative solutions to organic sector challenges. Finally, the project has been publicized in several Newsletters, including the Organic Center Scoop, which goes out to 23,689 individuals, and the Organic Trade Association Newsflash, which goes out to 3,500 subscribers. The project was also publicized in the Organic Report, a magazine with a readership of over 21,000. The Organic Center has also been ensuring

the project outcomes reach industry members, including the Organic Trade Association\'s Produce Safety Council. Finally, two educational outreach modules are in development to help reach a broad array of stakeholders: \"Science-based composting practices\" and \"Guidelines for manure use in produce production to enhance soil health\". Parts of the science-based composting practices module, which addresses manure treatment strategies and commonly-used non manure-based soil amendments, have been presented in draft form and are undergoing internal review for finalization. Guidelines for manure use in produce production to enhance soil health is being drafted for initial review. The Produce Safety Alliance has been in frequent communication with the researchers to ensure data from this project is being incorporated where appropriate into both modules. This includes the manure and soil health research from Activities 1 and 2 of this project. What do you plan to do during the next reporting period to accomplish the goals?Activity 1 (farm survey): We plan to finalize the statistical analysis to assess the risk factors with prevalence of foodborne pathogens, and generic E. coli in soil and produce. The web-base platform will be finalized and made accessible to the participant farmers. We plan to submit three manuscripts for publication. Activity 2 (experimental field trials): We plan finalize data analyses of the 3 field trials, as state-level and multi-regional, and for publication. Activity 3 (Outreach and Extension) fact sheet was developed to accompany the outreach modules to encourage other educators to use the materials and extend the reach of these outreach resources. It can be viewed at https://producesafetyalliance.cornell.edu/sites/producesafetyalliance.cornell.e du/files/shared/documents/FSMA-PSR-Documentation-Requirements-for-Commercial-So il-Amendment-Suppliers.pdf. Once the two educational outreach modules are completed and have been reviewed by the other collaborators on this project, both modules will be posted on the project website as well as the Produce Safety Alliance website and related social media accounts for public use as PSA Trainer Resources. Additionally, the modules will be linked to the Food Safety Resource Clearinghouse, a widely-referenced source of curated, publicly-available food safety resources. The two outreach modules will be presented in 2021 via two webinars through The Organic Center and the Produce Safety Alliance. The webinars presented through the Produce Safety Alliance will be presented during the monthly PSA Educator\'s calls, and will highlight the developed modules as supplemental resources for food safety educators. The PSA Educator\'s listserv reaches 440 individuals. In addition, the recorded webinars will be listed on the PSA website and available to the public. The webinar presented through The Organic Center will target organic growers who will directly benefit from the produce safety and soil health information in the outreach modules.

2017/09 TO 2018/08 Target Audience:The target audiences reached include various stakeholders in organic agriculture and produce food safety, including organic farmers, researchers, extension specialists, extension agents, policy makers, experts and industry working in organic agriculture. They were reached as part of the conferences, workshops and informal education activities (field days, one -to-one meetings with farmers) delivered through presentations at national and international meetings and conferences. In particular, many stakeholders were exposed to our research findings at the:1) 2018, The Second 1890 ARD & USDA-ARS Food Safety Consortium Symposium, April 23-35, 2018;USDA-ARS-Beltsville Agricultural Research Center, Beltsville, MD;2) 2018, Western Regional Center to Enhance Food Safety -2ndAnnual Meeting, March 27-28, UC Davis Conference Center, Davis, CA; 3) 2018International Association for Food Protection 2018 Annual Meeting (IAFP), July 8-11, 2018, Salt Lake City, UT ;4) 2018FSMA Produce Safety Rule Training for California Specialty Crop Growers.University of California, School of Veterinary Medicine UC Davis, February 21, 2018, Davis, CA; 5)2018 Center for Food Animal Health (CFAH) 2018 Stakeholder Workgroup Advisory Meeting, UC Davis, February 24, 2018, Davis, CA. In 2018, a total of seventeen certified organic farms were enrolled in the longitudinal multi-regional study in three growing regions (West: 9 California; Midwest: 4 Minnesota; and East: 4 Maine, 1 Maryland) and sampled. Organically certified farms were surveyed (monthly visits) and cooperated in farm survey from February - December, 2018 (Activity 1, farm survey study).In 2018, three certified organic centers/sites (one in each region) were selected for the experimental field trials. California: organic research farm at the University of California, Davis; Minnesota:SouthwestResearchandOutreachCenter(SWROC), Lamberton MN; and Maryland:University of Maryland Eastern Shore Research FarmMD(Activity 2, field trials). To reach our target audience the Organic Center disseminated a press releases to publicize the planned research. The Organic Center also developed a web portal where a description of the project, updates, and information has been posted. We also launched and maintain a social media campaign surrounding the research via The Organic Center and Organic Trade Association Facebook and Twitter accounts, and a unique Twitter account developed specifically for this project.The combined reach of our organizations\' social media pages is over 130,000 individuals for Facebook, and over 40,000 followers for Twitter. The experimental field trials located at the SWROC were featured during our 2018 Organic Field Day. Over 30 organic farmers attended the event to learn about the new research on organic farming that is underway at the SWROC. Every year the event has a morning field tour where the attendees ride along a wagon to visit selected research sites. And in 2018, this field trials were one of the highlieghted locations visited. Changes/Problems:In the second year, enrollement was expanded to include rotational grazing and expand geographical areas: 3 new farms were enrolled (1 CA, 1MN and 1 ME).

The number of samples per farm were increased to reflect the type of manure and produce grown. Note: In this report, we are presenting preliminary data from the year 2 corresponding to the growing season and sampling from February 2018 to December of 2018. What opportunities for training and professional development has the project provided?The project provided support for graduate/post-doctoral and undergraduate research, thus helping to build capacity for future professionals in microbiology, epidemiology and food safety.Dr. Pires mentored one Postdoctoral researcher, one PhD student, 2 junior specialists and 5 undergraduate students at UC Davis. Drs. Millner and Hashemco-mentored one master student. How have the results been disseminated to communities of interest?The results have been disseminated through outreach activities involvingorganic farmers, researchers, extension specialists, extension agents, policy makers, experts and industry working in organic agriculture. They were reached as part field days, one-to-one interactions, workshops and informal education activities delivered through presentations at national and international meetings and conferences. In particular, many stakeholders were exposed to our research findings at the: 1) 2018, The Second 1890 ARD & USDA-ARS Food Safety Consortium Symposium, April 23-35, 2018;USDA-ARS-Beltsville Agricultural Research Center, Beltsville, MD; 2) 2018, Western Regional Center to Enhance Food Safety -2ndAnnual Meeting, March 27-28, UC Davis Conference Center, Davis, CA. 3) 2018International Association for Food Protection 2018 Annual Meeting (IAFP), July 8-11, 2018, Salt Lake City, UT; 4) 2018. FSMA Produce Safety Rule Training for California Specialty Crop Growers.University of California, School of Veterinary Medicine UC Davis, February 21, 2018, Davis, CA; 5) 2018 Center for Food Animal Health (CFAH) 2018 Stakeholder Workgroup Advisory Meeting, UC Davis, February 24, 2018, Davis, CA. Activity 3: We are communicating our accomplishments to communities of interest using a variety of techniques.We pushed out a press release about the project, which can be found on 214 websites, with a potential total audience of 11,804,269 unique visitors per day.The total potential audience from tweets of the press release is 30,976 followers.Additionally, we are communicating with the public through a website which includes a description of the project and updates with pictures from the field. We have also leveraged the project outreach with the Organic Center\'s Google Ad Words Grant, which provides up to \$40,000 of funding per month for Google Ad Words.This campaign has generated a total of 279,127 clicks and 96,110,327 ad views over the last year.We are using social media to ensure that we reach a wide variety of stakeholders via the Organic Center and Organic Trade Association social media pages.The combined Twitter following for these organizations is 59,156 and the Facebook following is 151,765.Finally, the project has been publicized in several Newsletters, including the Organic Center Scoop, which goes out to 23,689 individuals, and the Organic Trade Association Newsflash, which goes out to 3,500 subscribers.The project was also publicized in the Organic Report, a magazine with a readership of over 21,000. Dr. Michele Jay-Russell (WCFS UC Davis), in her role as Manager of the Western Center of Food Safety, an FDA Center of Excellence at UC Davis, Dr. Jay-Russell communicates directly with FDA CFSAN partners in the divisions of Produce Safety, Whole Genome Sequencing, and Risk Assessment. This OREI project is complementary to other BSAAO-related research funded by FDA, and data sharing is encouraged with industry and regulatory stakeholders, especially as it relates to implementation of the FSMA Produce Safety Rule and development of a risk assessment for raw animal manure. What do you plan to do during the next reporting period to accomplish the goals?The Activity 1 (Longitudinal study and farm survey) of year 2 is completed with enrollment of seventeen certified organic farms were enrolled in the longitudinal multi-regional study in three regions.The farms were geographically spaced in diferents regions (Midwest: Southeast and East Minnesota and West Wisconsin; West: Central Coast, Central Valley, North Coast and Southern California; East Coast) to represent different growing climates including soil type and weather patterns and agricultural practices.These are small diversified farms growing many different crops (including kale, carrots, tomatos, radishes, lettuce, cucumbers, peppers, melons, beets and potatos) in small spaces. The number of crops per farm ranged from 1 to 4 types.This second year were able to assess the the survival rate of genericE. coliand foodborne pathogens in soil amemeded with raw manure.Weather, environmental data and farm -management data were collected during the study period.Statistical analysis will be conducted to determine the association between on-farm management factors, manure factors, soil factors (health and level of contamination), environmental factors and landscape on fresh produce in each of the following outcomes of interest: 1) the prevalence of pathogens (Salmonella, STEC andL. monocytogenes) in soil and produce;and 2) levels of microbial contamination indicators (i.e., genericEscherichia coli) in soil and produce. A customized self-risk assessment tool, based on a on-farm demographics and management practices, meteorological and environmental information will be developed and make available to the participant farmers.Microbial diversity is also being assessed for organic farm sites as well. Samples for soil health assessment were sent to University of Maine at the end of each season and data will be analyzed for associations with soil amendment treatment effects and microbial community analyses. The Activity 2 (Field trials, Objective 2):Because spinach and carrots are winter crops in Davis California, our second field trails extended into year 3. For the next report, we will analyze data from the 2018-2019 leafy greens and carrot trials. Additionally, by that time we will have more analysis comparing results from the 2 different field trials across growing seasons. Statistical analyses will be conducted for all three field trial sites. The Activity 3:The Organic Center and regional collaborators will continue with the outreach activities described before, byenganging a

diverse audience in outreach and using different information outlets. During the year 3 and 4,farmer-focused outreach and extension effortsaimed directly at organic farmers through the development and presentation of a webinar, continuing education modules and fact sheets for organic growers.

2016/09 TO 2017/08 Target Audience:The target audiences reached include various stakeholders in organic agriculture and produce food safety, including organic farmers, researchers, extension specialists, extension agents, policy makers, experts and industry working in organic agriculture. They were reached as part of the conferences, workshops and informal education activities (field days, one to one meetings with farmers) delivered through presentations at national and international meetings and conferences. In particular, many stakeholders were exposed to our research findings at the 1) 2017 Organic Confluences, Making Research Count, Washington, D.C. May 22-23, 2017; 2) International Association for Food Protection 2017 Annual Meeting (IAFP); Tampa, Florida July 9-12, 2017 and 3) Soil Summit 2017, Produce Safety Alliance & Institute for Food Safety at Cornell University. New York State Agricultural Experiment Station, Geneva, NY. March 28-29, 2017. In 2017, a total of sixteen certified organic farms were enrolled in the longitudinal multi-regional study in three growing regions (West: 8 California; Midwest: 3 Minnesota; and East: 4 Maine, 1 Maryland) and sampled. Organically certified farms were surveyed (monthly visits) and cooperated in farm survey from March - December, 2017 (Activity 1, farm survey study). In 2017, three certified organic centers/sites (one in each region) were selected for the experimental field trials. California: organic research farm at the University of California, Davis; Minnesota: Southwest Research and Outreach Center (SWROC), Lamberton MN; and Maryland: University of Maryland Eastern Shore Research Farm MD (Activity 2, field trials). Changes/Problems:In the first year, we weren\'t able to enroll 9 farms per region. Therefore to compensate the sample size in the overall study, we increased number of studied crops and type of manure per farm (e.g., number of samples within farm). In the second year of the study, we plan to expand the enrolment criteria (including rotational grazing) and geographic areas. What opportunities for training and professional development has the project provided?The project provided support for graduate/post-doctoral and undergraduate research, thus helping to build capacity for future professionals in microbiology, epidemiology and food safety. Dr. Pires mentored one Postdoctoral -researcher, one PhD student, 2 junior specialists and 4 udergraduate sutudents at UC Davis. Mark Hutchinson has mentored a master\'s student. How have the results been disseminated to communities of interest?The results have been disseminated through outreach activities involving organic farmers, researchers, extension specialists, extension agents, policy makers, experts and industry working in organic agriculture. They were reached as part field days, one-to-one interactions, workshops and informal education activities delivered through presentations at national and international meetings and conferences. In particular, many stakeholders were exposed to our research findings at the: 1) 2017 Organic Confluences, Making Research Count, Washington, D.C. May 22-23, 2017; 2) International Association for Food Protection 2017 Annual Meeting (IAFP); Tampa, Florida July 9-12, 2017, 3) Soil Summit 2017, Produce Safety Alliance & Institute for Food Safety at Cornell University. New York State Agricultural Experiment Station, Geneva, NY. March 28-29, 2017. What do you plan to do during the next reporting period to accomplish the goals?The second year (2017-2018) will include the year 2 of on-farm survey and field trials. Outreach and extension activies will be conducted as well.

IMPACT

2019/09 TO 2020/08 What was accomplished under these goals? Observed soil prevalence was 0.04% (1/2460) for E. coli O157, 7.3% (179/2460) for non-O157 STEC, 1.1% (26/2460) for Salmonella and 5.0% (122/2460) for L. monocytogenes during this 2-year study with samples from 0-180-dpa. For all 3 pathogen groups analyzed, prevalence peaked significantly just after manure application and decreased significantly by 30-dpa and onwards. A second peak for non-O157 STEC was observed after 120 dpa. Generic E. coli (gEc) in the soil, year, sampling day, season and presence of pathogens in manure samples were significant predictors of pathogens in the soil. Environmental factors (temperature, and precipitation) and soil factors (moisture, organic matter and micronutrients) were associated with pathogen prevalence. Animal manure type showed moderate evidence of association with pathogen prevalence. Soil samples amended with cattle or horse manure had lower concentrations of gEc compared to poultry manure. Environmental factors (humidity, precipitation, temperature and snow) and soil factors (micronutrients and organic matter) were associated with higher counts of gEc. This preliminary analysis provides science-based information to identify potential risk factors influencing foodborne pathogen persistence in pre-harvest produce production environments for soils amended with raw manure on organic production systems. Activity 2: Preliminary statistical analyses were conducted for the CA and MD field trials. A randomized complete block study was conducted on NOP-certified plots during 2017-2018 in California, Minnesota and Maryland. Survival of generic E. colirif-R (EC) on soil, tomatoes, radish/carrots and spinach was determined over 90-120(-180)-days for dairy manure (DM), horse manure (HM), poultry litter (PL), and

unamended (UnA) plots. California Trials: E. coli persisted in all HM, DM, PL, and UA plot soils growing carrot, spinach and tomato through 180 dpaEC survival in manured soil and transfer to crops. Reliance on wait-time intervals alone needs further evaluation. **PUBLICATIONS (not previously reported):** 2019/09 TO 2020/08 1. Type: Conference Papers and Presentations Status: Accepted Year Published: 2020 Citation: Pires A*, Ramos T, Millner P, Stover J, Pagliari P, Hutchinson M, Liley J, Rowley N, Aminabadi P, Baron J, Kenney A, Hashem F, Jay-Russel M. Risk factors associated with Escherichia coli persistence in soils amended with raw manure in certified organic farming systems in four regions of USA (P3-145) 2020 Annual IAFP Meeting, Virtual Meeting, October 26-28, 2020.(Poster Accepted, *presenter). 2. Type: Conference Papers and Presentations Status: Accepted Year Published: 2020 Citation: Pires A*, Ramos T, Millner P, Stover J, Pagliari P, Hutchinson M, Liley J, Rowley N, Aminabadi P, Baron J, Kenney A, Hashem F, Jay-Russel M. Risk factors associated with prevalence of foodborne pathogens in manured soils from USDA-NOP-certified organic farms in four regions of USA. (T3-04). 2020 Annual IAFP Meeting, Virtual Meeting, October 26-28, 2020. (Oral Presentation Accepted *presenter) 3. Type: Conference Papers and Presentations Status: Accepted Year Published: 2020 Citation: Aminabadi P*, Pires A, Millner P, Zwieniecka A, Ramos T, Jay-Russell. M. 2020. Transfer of indicator Escherichia coli to spinach, carrots and tomatoes grown in organic soil amended with raw animal manure in California, 2018-2019 (P3-150). 2020 Annual IAFP Meeting, Virtual Meeting, October 26-28, 2020.(Poster Accepted *presenter) 4. Type: Conference Papers and Presentations Status: Accepted Year Published: 2020 Citation: Kenney A*, Hashem F, Pires A, Jay-Russell M, Millner P, Collick, A. 2020. Precipitation and soil moisture effects on survival and transfer of Escherichia coli to fresh produce in manure-amended certified organic, (P3-74). Annual 2020 Annual IAFP (International Association for Food Protection) Meeting, Virtual Meeting, October 26-28, 2020. (Poster Accepted *presenter) 5. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: AL Kenney*, FM Hashem, P Millner, A Pires, M Jay-Russell. Assessing Escherichia coli Survival in Manure-Amended Certified Organic Soils and Transfer to Tomatoes, Radish, and Spinach Grown on the Eastern Shore of Maryland. Poster \# 1321. ASA-CSSA-SSSA International Annual Meetings (2019). November 10-13, 2019 (Poster* Presenter) 6. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Clements D, Bihn EA*. Using organic soil amendments to build soil health and enhance food safety. New England Vegetable and Fruit Conference, December 11, 2019. (Oral *presenter) 7. Type: Theses/Dissertations Status: Published Year Published: 2019 Citation: AL Kenney*. Master of Science Thesis: Assessing Escherichia coli Survival in Manure-Amended Certified Organic Soils Cultivated with Tomatoes, Radish, and Spinach on the Eastern Shore of Maryland. Assessing Escherichia coli Survival in Manure-Amended Certified Organic Soils Cultivated with Tomatoes, Radish, and Spinach on the Eastern Shore of Maryland. December 2019

2017/09 TO 2018/08 What was accomplished under these goals? Activity 1:In 2018, a total of 17 certified organic farms were enrolled in the longitudinal multi-regional study in three growing regions (West: 9 CA; Midwest: 4 MN; and East: 4 ME, 1 MD). Farms were surveyed (monthly visits, 8 total) and cooperated in farm survey from Feb-Dec 2018. Manure (cattle, poultry, horse and small ruminants), soil, irrigation water and produce (leafy greens, tomatos, peppers, radishes, cucumbers, melons, carrots, beets) were collected for a period of 7 to 8 months Soil samples were analyzed for composition, soil health and microbial populations.The presence of 4 foodborne pathogens (non-O157 Shiga toxin-producingEscherichia coli(STEC),E. coliO157:H7,Listeria monocytogenesandSalmonella) and contamination indicators (genericE. coli) were assessed in manure, soil, irrigation water and produce. Most Probable Number (MPN) methods were used to quantify genericE. coliand confirmed via PCR insoil samples, water and fresh produce. Overall, 53.7% of samples were positive forE. coli(755/1360): 60.3% soil and, 22.5% produce, and 23.7% water. Average MPN values were: in CA, 0.60 log MPN/100g dryfor soil,0.11 log MPN/100g for produce. In MD, 1.06 log MPN/100gfor soil, 0.14 log MPN/100gfor produce. In ME, 0.55 log MPN/100g for soil (range 0 - 4.94), 0.40 log MPN/100g for produce. In MN, 1.19 log MPN/100g for soil, 0.23 log MPN/100g for produce. Populations of genericE. colidecreased substantially by 120 days post manuring on 10 of 17 farms. Samples were cultured for STEC,E. coliO157:H7,Listeria monocytogenesandSalmonella. Manure samples were positive for non-O157 STEC (7.9%, 18/228),E. coliO157:H7 (1.32%, 3/228) andL. monocytogenes(3.9%, 9/228). The prevalence of non-O157 STEC in soil samples was 10.4% (73/700), 7.7% (80/1043), 5.2% (10/196), and 4.1% (16/386), in MN, CA, MD, and ME, respectively.L. monocytogeneswas detected in 7.3% (31/700), 5.5% (47/1043), 4.4% (25/196), and 4.2% (1/196) of soil samples from MN, CA, ME and MD, respectively.Salmonellawas detected in 1.1% (26/2295) of soil samples. Non-O157STEC andL. monocytogeneswere detected in soil up to 30 and 90 days post-manuring, respectively. All water samples were negative for foodborne pathogens (0/38). Produce results are pending. Soil health and compositon were evaluated. Farm-management practices, environment factors (weather and temperature/ soil moinsture) were recorded. Soil microbial population assessment is pending. Activity 2:In 2018, three certified organic centers (one in each region) were selected for the field trials. CA: research plots at certified organic field at the University of California, Davis; MN:SouthwestResearchandOutreachCenter(SWROC), Lamberton MN; and MD:University of Maryland Eastern Shore Research Farm, MD. At each center randomized

complete block design was conducted.A randomized complete block design with 4 replications for each of 4 treatments: horse manure (HM), dairy manure (DM), poultry litter (PL) and unamended (UnA), were established at the at each research site.The organic soils amended with raw animal manure and unamended soils were inoculatedwith a three-strain cocktail of non-pathogenic, rifampicin-resistantE. coli (ECrif-R)at 6 log CFU/ml (1-L per 2m2plot). Soils were analyzed on days pre- and post-inoculation (0-180 days).Transfer of EC to produce was determined at 90 and 120 days post-application of manure and ECinoculum. In 2017-2018, at MD site, certified-NOP silty-loam field-plots were amended DM or HM, PL, or UnA, before spray-inoculating with a mixture of rifampicin-resistantE. coli(ECrif-R) at 6 log CFU/mL. Composite-core samples were enumerated(MPN) on 0, 30, 60, 90, 120-dpi, with harvested produce enrichments on 90 and 120-dpi. In radish soils, ECrif-Rpopulations declined from 100% positive (n=32) on 0-dpi to 0-20% positive for all treatments by 90-120-dpi (n=64), but 100% persistence on bulbs for all 2017 treatments; 2018 PL and DM-amendments supported 50% positive (n=16) transfer of ECrif-Rto 120-dpi bulbs. For tomato soils, ECrif-Rpopulations at 100% positive (n=32), 0-dpi (2017, 2018) declined to 20% for all manured treatments by 90-dpi, but 30% and 40% were positive by 120-dpi in DM and PL 2017 plots respectively; army worm-frass resulted in 100% contamination of all tomato fruits (n=32). In 2018, ECrif-Rdeclined to 10-20% by 90-120-dpi with no transfer to tomato fruits. Spinach soil ECrif-Rpopulations varied substantially during 2017-2018 with 100% transfer to harvested 30-g samples/plot, (n=32) in 2017; the 2018 crop failed. At the MN site located at the SWROC, the crops grown were tomoatoes, spanich and radish. All crops grew well and soil and produce samples were collectedand analyzed according to the research plan. The transfer and enumeration of survivingE. colionto the harvested tomatoes and radishes was assayed. In addition, to determining the survival of the inoculatedECrif-Rcocktail samples, n=48 every 4-weeks, were collected and shipped to USDA-ARS in Beltsville, MD, from all field plots comprising manure amendment treatments (DM, HM, PL and UnA). Upon arrival, subsamples were analyzed directly for survivingE. coli. In addition, and a subsample was frozen at -80oC for subsequent assay of microbial community diversity; these assays are still in progress for years 2017 and 2018. CA, winter crops (2017-2018): The first leafy greens (spinach) and root crop (carrot) field trials were initiated in 2017 (fall) and completed in 2018 (spring) at the UC Davis certified organic research farm.Chicken litter (CL), dairy manure solids (DMS), and horse manure (HM) were tilled separately into four replicate soil plots. Plots were inoculated with a three-strain cocktail of rifampicin-resistantE. coli(108MPN/g). Controls included un-amended (UA) and un-inoculated (UI) plots. Organic spinach and carrot seeds were planted 12 days post-application (dpa). Soil samples were collected from 0-180-dpa. Spinach leaves and carrots were harvested on 98-/131- and 127-/168-dpa, respectively.E. colipopulations were quantified using direct plating and Most Probable Number (MPN) methods.E. colipersisted in soil from all manure-amended plots through 180-dpa. Manure and crop type influencedE. colisurvival. In the spinach field, DMS-amended soil had significantly higherE. colicounts compared with UA- and HM-amended plots (p-value\<0.05). In contrast, counts were significantly higher in soil from HM- compared with CL- and DMS-amended plots in the carrot field (p-value\<0.05). Transfer of inoculum to spinach leaves was observed on 98-dpa (average, 0.9 x 10 MPN/g) and 131-dpa (average, 0.01 x 10 MPN/g). Carrot samples were positive at 127-dpa (average, 1.5×102MPN/g) and 168-dpa (average, 1.6×102MPN/g). The second winter field trials (spinach and carrots) are underway and will be completed in Spring 2019. CA Summer Crops (2018): The second tomato field trial was conducted during the 2018 growing season (spring-summer). CL,DMS, and HM were inoculated as described above in May 2018. Controls included UA and UI plots. Each plot was sampled and analyzed for inoculum concentration using most probable number (MPN) and direct plating (CFU) in the following 0, 1, 3, 7, 14, 28, 56, 90, 120, 150 and 180 dpa. Drip irrigation was setup followed by covering the plots with white plastic mulch then organic red Brandywine tomatoes were transplanted on 14-dpa.E. colipersisted in soil from all manure-amended and the unamended plots through 180-dpa with the average of 1.2 MPN/g. Tomato fruits were harvested on 120, 133 and 153-dpi. On day 133 one tomato bag collected form a HM plot tested positive for low levels of rif-resistanceE. colitransfer (3×10-4MPN/g) to the fruits.Preliminary findings from field trials in CA suggest thatE. coliin manure-amended soil may persist and be transferred to leafy greens and root crops in organic production. **PUBLICATIONS (not previously reported):** 2017/09 TO 2018/08 1. Type: Journal Articles Status: Published Year Published: 2018 Citation: Pires AFA, Millner PD, Baron J, Jay-Russell M. 2018. Assessment of Current Practices of Organic Farmers Regarding Biological Soil Amendments of Animal Origin in a Multi-Regional US Study. Food Protect. Trends 2018. 38 (5) 347-362. (Sinergetic activities/Products) 2. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Aminabadi P, Patterson L, Pires A, Millner P, Jay-Russell. M. 2018. Field validation of minimum application intervals for raw animal manure used as a soil amendment at a certified organic research farm in California, (Abstract P1-182) Annual IAFP Meeting 2018, Salt Lake City, UT, July 8-11. 3. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Kenney A, Millner P, Pires A, Jay-Russell M, Hashem F. 2018. Survival of E. coli in Manure-amended Certified Organic Soils and Transfer to Tomatoes, Radish, and Spinach in Maryland Eastern Shore, American Society for Horticultural Science (ASHS 2018), Washington D.C., July 30-August 3. 4. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Kenney A, Hashem F, Pires A, Jay-Russell M, Millner P. 2018. Survival of Escherichia coli in manure-amended soils and transfer to tomato, radish, and spinach on a Maryland

certified organic farm (Abstract P1-139) Annual IAFP Meeting 2018, Salt Lake City, UT, July 8-11. 5. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Ramos T, Jay-Russel M, Millner P, Stover J, Pagliari P, Hutchinson M, Liley J, Hashem F, Pires A. 2018. Multi-regional risk analysis of manure use: survival and persistence of foodborne pathogens in soil and contamination risk of fresh produce in certified organic farms, (Abstract T3-01) Annual IAFP Meeting 2018, Salt Lake City, UT, July 8-11. 6. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Ramos T, Jay-Russel M, Millner P, Stover J, Pagliari P, Hutchinson M, Liley J, Hashem F, Pires A. 2018. A multi-regional risk analysis of raw manure soil amendment use on certified organic farms: survival of generic Escherichia coli in soil and produce (Abstract T3-03) Annual IAFP Meeting 2018, Salt Lake City, UT, July 8-11. 7. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Kenney A*, Hashem F, Pires A, Jay-Russell M, Millner P. Survival and persistence of non-pathogenic of E. coli in Manure-Amended certified organic soils and transfer to tomato, radish, and spinach grown on eastern shore of Maryland. The Second 1890 ARD & USDA-ARS Food Safety Consortium Symposium, April 23-35, 2018; USDA-ARS-Beltsville Agricultural Research Center, Beltsville, MD 8. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Pires A, Multi-regional risk analysis of farm manure use for organic fresh produce: an integrative approach In Presentations of Successful Cooperative Projects Session. The Second 1890 ARD & USDA-ARS Food Safety Consortium Symposium, April 23-35, 2018; USDA-ARS-Beltsville Agricultural Research Center, Beltsville, MD 9. Type: Other Status: Other Year Published: 2018 Citation: Pires, A, February 21, 2018. FSMA Produce Safety Rule Training for California Specialty Crop Growers. Organizer & Speaker. University of California, School of Veterinary Medicine UC Davis, February 21, 2018, Davis, CA. 10. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Jay-Russell M. Research Updates on Wildlife Co-Management/Soil Summit. Invited Speaker Western Regional Center to Enhance Food Safety (WRCFS):2nd Annual Meeting, March 27-28, 2018, UC Davis Conference Center, Davis, CA 11. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Pires A, Research Updates on Soil Amendments Soil Summit. Invited Speaker Western Regional Center to Enhance Food Safety (WRCFS):2nd Annual Meeting, March 27-28, 2018, UC Davis Conference Center, Davis, CA 12. Type: Other Status: Other Year Published: 2018 Citation: Pires, A, February 23, 2018. Food Safety: Research Updates. Invited Speaker. Center for Food Animal Health (CFAH) 2018 Stakeholder Workgroup Advisory Meeting, UC Davis, February 24, 2018, Davis, CA.

2016/09 TO 2017/08 What was accomplished under these goals? Activity 1: Sixteen certified organic farms were enrolled in the longitudinal multi-regional study in three regions (8 California, 4 Maine, 3 Minnesota, and 1 Maryland) and sampled from March to December, 2017. Frequent farm visits (8 totall) were conducted throughout the growing season to collect manure, soil, water and produce samples. Samples were analyzed for a wide array of parameters, including nutrients, soil health quality and microbial populations. Manure (e.g., cattle, poultry, horse and small ruminants), soil, irrigation water and produce (e.g., leafy greens, tomtatos, peppers, radishes, cucumbers, melons) were collected for a period of 7 to 8 months. The presence and/or persistence of 4 foodborne pathogens (non-O157 Shiga toxin-producing Escherichia coli (STEC), E. coli O157:H7, Listeria monocytogenes and Salmonella) were assessed in manure, soil, irrigation water and produce (Objective 1.4.) and contamination indicators generic E. coli) in fresh produce (Objective 1.4.). Most Probable Number (MPN) methods were used to quantify generic E. coli soil samples (monthly), water and fresh produce (at harvest). Quantitative and qualitative recovery of E. coli in each sample was achieved via selective and differential culturing methods and confirmed via PCR. Overall, 55.6% of samples were positive for E. coli (755/1360): 55.5% soil and, 3.7% produce. Average MPN values were: in California, 1051 MPN/100g dry for soil (range 0 - 145,190), 15.6 MPN/100g for produce (range 0 - 123). In Maryland, 2,026 MPN/100g for soil (range 0 - 33,776), 11.5 MPN/100g for produce (range 0 - 22.5). In Maine, 1,220 MPN/100g for soil (range 0 - 87,736), 149.7 MPN/100g for produce (range 0 - 2,514). In Minnesota, 2,963 MPN/100g for soil (range 0 - 33,776), 885 MPN/100g for produce (range 0 - 15,750). The generic E. coli counts decreased considerably 120 days post manure application on 10 out of 16 farms. One irrigation water sample was generic E. coli positive. Samples were cultured for non-O157 Shiga toxin-producing Escherichia coli (STEC), E. coli O157:H7, Listeria monocytogenes and Salmonella. Manure samples were positive for non-O157 STEC (10.5%, 11/105), E. coli O157:H7 (0.95%, 1/105) and L. monocytogenes (6.7%, 7/105). The prevalence of non-O157 STEC in soil samples was 6% (6/100), 8.2% (15/196), 13.4% (48/358) and 13.9% (70/502) in MD, ME, MN and CA farms, respectively. L. monocytogenes was detected in 1% (1/100), 5.4% (27/502), 7.3% (26/358) and 12.8% (25/196) of soil samples in MD, CA, MN and ME, respectively. Salmonella was found in 0.5% (1/196) of soil samples in Maine. Non-O157 STEC and L. monocytogenes were detected in soil up to 180 days and Salmonella up to 120 days post-manure application. Only one produce sample was positive for L. monocytogenes. All water samples were negative for foodborne pathogens. Soil health and compositon parameters were evaluated (Objective 1.2). On farm-management practices, environment factors (weather and temperature/soil moinsture) were recorded (Objective 1.1.). Soil microbial population assessment is pending (Objective 1.3.) Individual farm reports with findings of year 1 were provided to each participant farm. Activity 2: In 2017, three certified organic centers/sites (one in each region)

were selected for the experimental field trials. California: research plots at certified organic field at the University of California, Davis; Minnesota: Southwest Research and Outreach Center (SWROC), Lamberton MN; and Maryland: University of Maryland Eastern Shore Research Farm, MD (Activity 2, field trials). At each center/ site a randomized complete block design was conducted with 4 replications and amended with poultry litter, horse manure and dairy solids and unamended. The organic soils amended with raw animal manure and unamended soils were inoculated with a three-strain cocktail of non-pathogenic, rifampicin-resistant E. coli (rif-EC) at 6 log CFU/ml (1-L per 2m2 plot). A randomized complete block design with 4 replications for each of 4 treatments: horse manure (HM), dairy manure (DM), poultry litter (PL) and unamended (UnA), were established at the at each research site. Soils were analyzed on days 0, 7, 14, 28, 60, 90, and 120, 150, 189 pre- and post-inoculation. Transfer of EC to tomatoes, spinach, and radish was determined at 90 and 120 days post-application of manure and EC inoculum. Maryland: The EC survival was higher and more persistent in the PL-amended soils, than in any other treatment. In all tomato plots, yellow-striped army worms invaded and caused major crop damage by day 90, and were suspected of contributing to the large number of EC-positive tomato fruits when assayed. Spinach did not mature before frost set, and radishes from all treatments, except UnA, had surviving EC in the initial wash water of the bulbs. California: Organic heirloom tomatoes were transplanted in field plots (4 m2) amended with untreated dairy solids (DS), horse manure (HM), poultry litter (PL), and unamended controls (UA) at a certified organic farm in Davis. Soils at 90 dpi, had log reductions of rif-EC populations of 4.3 (DS), 5.1 (HM), 5.3 (PL) and 6.3 (UA); at 120 dpi, log reductions were 5.3 (DS), 5.8 (HM), 6.2 (PL) and 5.5 (UA). On the final sample day (180 dpi), the concentration of rif-EC (MPN/g) had decreased to 3.7 (DS), 18.0 (HM), 0.7 (PL), and 0.6 (UA). The inoculum was not detected in any tomato samples. Experiment day and rif-EC concentration (log MPN/g) were significantly associated (P\< 0.001), but not manure type. Spinach results are pending. Minnesota field trails results are pending. Soil microbial community profile of the field trials is pending. **PUBLICATIONS (not previously reported):** 2016/09 TO 2017/08 1. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Pires A, Tocco P, Millner P. A Research Framework to Assess Pathogen Prevalence and Survival in Raw Manure Used in Produce Production in Biological Soil Amendments of Animal Origin and the Food Safety Modernization Act: Challenges and Opportunities Going Forward. International Association for Food Protection 2017 Annual Meeting (IAFP); Tampa, Florida July 9-12, 2017; Tampa, Florida July 9-12, 2017. (S27, Seminar). 2. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Pires A, Jay-Russell M. May 23, 2017. Integrative Research: Approaches in Organic Agriculture. Case Study3: Manure Safety Panel. Invited Speaker. 2017 Organic Confluences. Making Research Count, Washington, D.C. May 22-23, 2017. 3. Type: Other Status: Other Year Published: 2017 Citation: Pires A, Jay-Russell M. Soil Summit 2017, Produce Safety Alliance & Institute for Food Safety at Cornell University. Participant. New York State Agricultural Experiment Station, Geneva, NY. March 28-29, 2017.

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Partnership to Explore Integrated Systems for Sustainable High Tunnel Organic Vegetable Production in the Southeast Region

Accession No.	1010455
Project No.	FLA-HOS-005530
Agency	NIFA FLA\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2016-51300-25738
Proposal No.	2016-04470
Start Date	01 SEP 2016
Term Date	31 AUG 2017
Grant Amount	$49,983
Grant Year	2016
Investigator(s)	Zhao, X.
Performing Institution	UNIVERSITY OF FLORIDA, G022 MCCARTY HALL, GAINESVILLE, FLORIDA 32611

NON-TECHNICAL SUMMARY

The long-term goal of the project is to develop integrated high tunnel systems to promote the growth and expansion of organic vegetable production in the Southeast. High tunnel systems hold unique potential to address the challenges of organic vegetable production in the Southeast by providing an economical protected agriculture system that may help growers overcome many pest-related and soil and water management issues that currently limit their chances of success. By building a strong partnership with organic producers and other stakeholders, this planning project is aimed at identifying research, education, and extension priority areas that will address systematically the major challenges and key issues with organic high tunnel production and management, targeting long-term environmental and economic sustainability. A diverse group of organic growers, organizations linking growers and consumers, and industry sectors serving the organic producers will be actively engaged and participate in the two project meetings organized by the planning project team. An organic grower survey will also be conducted in FL and GA to identify critical needs in developing integrated organic high tunnel systems in the Southeast. A Regional Advisory Panel will be formed to provide overall guidance for development of the project. Various avenues will be used for project information dissemination and outreach. This planning project will produce an integrated project full proposal with a high probability of success for 2017 submission.

OBJECTIVES

The objectives of this planning project include:Objective 1: Build and strengthen new and existing partnerships with organic producers and other stakeholders by involving them in project planning and brainstorming and outcome delivery. Objective 2: Identify the critical stakeholder needs for organic high tunnel system research, education, and extension through a multi-state organic grower survey. Objective 3: Develop a multi-regional integrated project proposal on organic high tunnel vegetable production systems to address the critical stakeholder needs and priority areas for research, education, and extension identified in this planning project. Awarded -- see 2017 summary. **FINAL REPORT** 09/01/16 to 08/31/18 **Outputs** Target Audience:The target audience includes certified organic vegetable growers, transitional organic producers, growers who are interested in organic vegetable production, high tunnel growers, producers interested in using high tunnels for organic vegetable crops, researchers and educators, extension personnel, service providers, agricultural

consultants, industry representatives, and the general public. Changes/Problems:Due to the recent hurricane disaster, NIFA has unilaterally extended this award to provide additional time to complete the project. With the one-year no-cost extension, we were able to analyze all the data from the multi-state organic grower survey and further disseminate the project findings for successful completion of this planning project in 2018. What opportunities for training and professional development has the project provided?We actively involved graduate students in this project to participate in our project meetings,planning activities, and project dissemination activities. In collaboration with the Florida Certified Organic Growers and Consumers Inc., we organized a high tunnel and organic vegetable production workshop which attracted over 50 participants including growers, researchers, educators, and industry representatives. Various topics on improving organic vegetable production and high tunnel management were discussed during the workshop. Some of the project information has been incorporated into the class content for undergraduate courses on organic horticultural systems at the University of Florida. How have the results been disseminated to communities of interest?Project information and results have been disseminated through project meetings and workshops.Project findings were also presented at the American Society for Horticultural Science 2018Annual Conference. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? Objective 1: Build and strengthen new and existing partnerships with organic producers and other stakeholders by involving them in project planning and brainstorming and outcome delivery. We organized our first full-day project planning meeting on October 6, 2016 at the Tifton campus of University of Georgia. This meeting, consisting of a series of interactive sessions, brought together researchers, extension agents, organic vegetable producers, organic grower organizations, and industry stakeholders from FL and GA involved in the project team to discuss the development of the project.At this project planning meeting, results from the high tunnel grower phone interview conducted in September 2016 were discussed. Project researchers from the University of Florida, University of Georgia, Florida A&M University, and USDA ARS presented up-to-date information about their research and extension programs related to organic high tunnel vegetable production systems in FL and GA. Two extension agents (one from University of Florida and the other from Fort Valley State University) also discussed their work with high tunnel vegetable producers. Representatives from Florida Certified Organic Growers and Consumers Inc., Georgia Organics, NRCS, and high tunnel structure and organic fertilizer manufacturers, and collaborative organic growers using high tunnels participated actively in all the discussions and provided constructive feedback. Focus areas for the organic high tunnel grower survey instrument development were identified and an implementation plan was discussed. The project team also agreed that a multi-regional integrated project proposal should come out of this planning project and the strategic plan for full proposal development was further discussed. Our second project meeting was held at the University of Florida in Gainesville on December 20, 2016 with the main objective of discussing the development of a multi-regional integrated project proposal for submission to the 2017 OREI program by January 19, 2017. An updated report from the grower phone interview was presented to the project team. The full proposal title, research priorities and activities, and focus areas at each institution were discussed. Other meeting agenda items included discussions of on-farm research approach, regional advisory panel, stakeholder engagement, and outreach plan. An action plan was developed at the end of the meeting to guide the successful development of the full proposal. The final project meeting was held in Gainesville on July 24, 2017 to discuss project activities and dissemination as well as partnership building for the newly funded multi-regional integrated project. Following the project meeting, a workshop on high tunnel and organic vegetable production was delivered by the project team in the afternoon, which attracted over 50 participants. Objective 2: Identify the critical stakeholder needs for organic high tunnel system research, education, and extension through a multi-state organic grower survey. In order to obtain preliminary information for developing the multi-state organic grower survey questionnaire, we conducted grower phone interviews during September and December 2016, which involved four Florida farmers and four Georgia farmers. The phone interview questions covered a wide range of topics associated with high tunnel vegetable production including crop selection, soil building practices, high tunnel benefits, economic advantages and disadvantages, barriers, research priorities, high tunnel interest, and decision factors. A follow-up questionnaire was used to verify the phone interview results for further development of the comprehensive multi-state grower survey. Eight grower participants responded to this questionnaire by ranking the six broad topical areas determined by the project team in terms of importance as an area for research: 1). decisions about the cropping system (crop selection, cover crops, and crop rotations); 2). ventilation and temperature management; 3). soil and nutrient management; 4). pest and disease management; 5). economic issues; and 6). attracting pollinators and beneficial insects. This follow-up questionnaire verified our interpretation of what growers indicated in the phone interviews and made sure we reached valid results about their needs and priorities. We then developed and distributed a questionnaire to organic vegetable growers using high tunnels in Florida and Georgia. We asked respondents to rank specific crop selections and research need topics. The two highest ranked crops for organic high tunnel production were salad greens and tomatoes. The top research need areas for high tunnel organic vegetable production identified in this multi-state grower survey included disease, weed, and pest management, environmental control, soil fertility and crop nutrient management, and crop and cultivar selection.

Specific research topics in these research need areas were also ranked by respondents. For example, the following three research topics were rated most important with respect to disease, weed, and pest management: crop and/or cultivar selection, evaluating bio-control for insect pests, and cover crop evaluation. Ventilation management protocols for periods of high heat and high humidity, crop and/or cultivar selection, and evaluating shade cloth to reduce temperature and modify high tunnel environment were important research topics about environmental control. The three research topics rated most important for soil fertility and crop nutrient management included evaluating soil amendments, optimizing irrigation practices and timing, and evaluating effects of high tunnel environment on nutrient release patterns of fertilizers and soil amendments. The findings from this multi-state grower survey will direct our research objectives in future high-tunnel projects focused on improving organic vegetable production and management. Objective 3: Develop a multi-regional integrated project proposal on organic high tunnel vegetable production systems to address the critical stakeholder needs and priority areas for research, education, and extension identified in this planning project. Through partnership building and extensive activities reaching out to growers and stakeholders, this planning project allowed us to successfully develop a multi-regional integrated project proposal that was selected for funding by the 2017 OREI grant program. The long-term goal of the newly funded project is to develop a strategic plan for research and extension in organic high tunnel vegetable production to address a more complete range of needs. The multi-regional integrated project is focused on the following research objectives: 1). Assess the efficacy of environmental control measures including shading, ventilation, and other cooling approaches on crop growth, yield, and quality of organically grown solanaceous vegetables and leafy greens under high tunnels; 2). Optimize planting time for high-tunnel produced tomatoes and leafy greens for early production and season extension and examine its impacts on nutrient availability and dynamics in organically managed high tunnel systems; 3). Determine the influence of integrated nutrient management practices on nutrient use efficiency and soil quality in high tunnel organic vegetable production; 4). Monitor and characterize plant pathogens infecting high priority organic high tunnel crops, and integrate biological products and cultural practices into organic vegetable disease management for high tunnels; 5). Monitor population of arthropod pests and beneficials in high tunnel organic vegetable cropping systems; 6). Develop cultural and biological alternatives for managing whiteflies and aphids; and 7). Analyze on-farm economic viability of high tunnel organic vegetable production and identify the factors influencing high tunnel adoption among organic growers. **Publications** - Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2018 Citation: Sattanno, K., M.E. Swisher, X. Zhao, Z. Gao, and Z. Black. 2018. Growing high tunnel use for organic vegetable production in the Southeast. American Society for Horticultural Science Annual Conference, Washington, DC. - Type: Other Status: Other Year Published: 2017 Citation: D&#65533;az-P&#65533;rez, J.C. 2017. Shading nets as a means to reduce heat stress in bell pepper. University of Florida High Tunnel and Organic Vegetable Production Workshop, Gainesville, FL. - Type: Other Status: Other Year Published: 2017 Citation: Frey, C. 2017. High tunnel organic spinach production research trial results. University of Florida High Tunnel and Organic Vegetable Production Workshop, Gainesville, FL. - Type: Other Status: Other Year Published: 2017 Citation: Gannon, A. Trap crop strategies for southern green stink bug Nezara viridula. University of Florida High Tunnel and Organic Vegetable Production Workshop, Gainesville, FL. - Type: Other Status: Other Year Published: 2017 Citation: Hodges, A. 2017. Trapping true bugs Preliminary summary of findings for organic tomatoes in Florida. University of Florida High Tunnel and Organic Vegetable Production Workshop, Gainesville, FL. - Type: Other Status: Other Year Published: 2017 Citation: Legaspi, J. 2017. Conservation biological control. University of Florida High Tunnel and Organic Vegetable Production Workshop, Gainesville, FL. - Type: Other Status: Other Year Published: 2017 Citation: Magstadt, K. 2017. Understanding high tunnels, and how they can help me. University of Florida High Tunnel and Organic Vegetable Production Workshop, Gainesville, FL. - Type: Other Status: Other Year Published: 2017 Citation: Mesh, M. 2017. Organic certification and cost share program. University of Florida High Tunnel and Organic Vegetable Production Workshop, Gainesville, FL. - Type: Other Status: Other Year Published: 2017 Citation: Thaxton, B. 2017. High tunnel tomato cultivar trial for early spring production. University of Florida High Tunnel and Organic Vegetable Production Workshop, Gainesville, FL. - Type: Other Status: Other Year Published: 2017 Citation: Zhao, X. 2017. Opportunities and challenges for high tunnel organic vegetable production in Florida. Florida A&M University High Tunnel Workshop, Quincy, FL. - Type: Other Status: Other Year Published: 2017 Citation: Zhao, X. 2017. High tunnel organic tomato production research trial results. University of Florida High Tunnel and Organic Vegetable Production Workshop, Gainesville, FL.

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Cioa 2- Carrot Improvement for Organic Agriculture with Added Grower and Consumer Value

Accession No.	1010332
Project No.	ILLW-2016-04393
Agency	NIFA ILLW\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2016-51300-25721
Proposal No.	2016-04393
Start Date	01 SEP 2016
Term Date	31 AUG 2020
Grant Amount	$1,999,979
Grant Year	2016
Investigator(s)	Simon, P.
Performing Institution	AGRICULTURAL RESEARCH SERVICE, 1815 N University, Peoria, ILLINOIS 61604

NON-TECHNICAL SUMMARY

Organic growers need vegetable varieties that are adapted to organic growing conditions and have market qualities demanded by organic consumers. In carrots, weed competition, nutrient acquisition, nematodes, and disease pressure are particularly critical challenges to both fresh market carrots and carrot seed production, while flavor, appearance, and nutrition are key market qualities. This project will deliver improved carrot varieties for organic producers and consumers; improved understanding of cultivar performance in organic systems; improved understanding of how carrot genotypes interact with the root microbiome to access key nutrients under limiting environments and avoid heavy metal uptake; and a breeding model that may be adapted to other crops for organic cultivar development. Organic farmers, students, and industry stakeholders in six states will participate in the breeding, variety trials, and planning aspects of the project. Project results will be disseminated nationally. The project will train graduate and undergraduate students in plant breeding, soil microbial ecology, and vegetable trial development for organic systems through research and field assistant positions. New cultivars adapted to organic conditions will enhance organic vegetable production and organic farmer economic returns, thus facilitating expansion of organic agriculture in the USA. Publically available breeding lines, including germplasm with nematode resistance, will support organic seed industry development of additional new cultivars. The development of improved carrot varieties with greater tolerance to biotic and abiotic stress will bring broad environmental benefits by reducing the need for off-farm inputs. Organic seed companies, producers, and consumers will benefit from access to new cultivars.

OBJECTIVES

1 - Conduct advanced on-farm crop research to advance organic production through a systems approach to breeding and on-farm assessment that includes: a) evaluating and breeding nutrient-rich, disease and nematode resistant carrots in infested fields; b) determining how carrot genotypes interact with their root microbiome to access key nutrients under limiting environments and avoid heavy metal uptake; c) trialing standard and organically available carrot cultivars and new breeding stocks on organic agricultural research stations and commercial organic growers\' fields; and d) publishing results of agronomic, storage, and tasting analysis on the web and in print publications to inform growers and facilitate organic seed usage.2- Develop and demonstrate

educational tools for Cooperative Extension personnel and other agricultural professionals, partnering with eOrganic to deliver online extension resources, including new educational publications, variety trial publications, and webinars related to organic carrot production and breeding topics. Additionally, the project will engage Cooperative Extension personnel through field days, agricultural conferences, and other outreach activities.3- Strengthen organic crop seed systems by breeding and releasing new publically available cultivars and breeding lines to the organic seed industry that address critical needs prioritized by organic stakeholders. Specific activities addressing this priority include: a) publically releasing new cultivars and inbred lines of nutrient-rich, disease and nematode resistant carrots with improved nutrient acquisition, weed tolerance, and long storage ability, with excellent flavor; b) developing new breeding populations that combine critical traits and advance future cultivar development; c) providing carrot breeding tools for seed companies, production information for growers, and flavor, nutritional quality, and environmental impact information for consumers about improved organic carrot germplasm; d) selecting for greater acquisition of key plant nutrients and reduced capacity to take up heavy metals; and e) evaluating diverse carrot germplasm for priority traits under organic management conditions in diverse environments and selecting and increasing promising populations to advance future breeding efforts.1 - Conduct advanced on-farm crop research to advance organic production through a systems approach to breeding and on-farm assessment that includes: a) evaluating and breeding nutrient-rich, disease and nematode resistant carrots in infested fields; b) determining how carrot genotypes interact with their root microbiome to access key nutrients under limiting environments and avoid heavy metal uptake; c) trialing standard and organically available carrot cultivars and new breeding stocks on organic agricultural research stations and commercial organic growers\' fields; and d) publishing results of agronomic, storage, and tasting analysis on the web and in print publications to inform growers and facilitate organic seed usage.2- Develop and demonstrate educational tools for Cooperative Extension personnel and other agricultural professionals, partnering with eOrganic to deliver online extension resources, including new educational publications, variety trial publications, and webinars related to organic carrot production and breeding topics. Additionally, the project will engage Cooperative Extension personnel through field days, agricultural conferences, and other outreach activities.3- Strengthen organic crop seed systems by breeding and releasing new publically available cultivars and breeding lines to the organic seed industry that address critical needs prioritized by organic stakeholders. Specific activities addressing this priority include: a) publically releasing new cultivars and inbred lines of nutrient-rich, disease and nematode resistant carrots with improved nutrient acquisition, weed tolerance, and long storage ability, with excellent flavor; b) developing new breeding populations that combine critical traits and advance future cultivar development; c) providing carrot breeding tools for seed companies, production information for growers, and flavor, nutritional quality, and environmental impact information for consumers about improved organic carrot germplasm; d) selecting for greater acquisition of key plant nutrients and reduced capacity to take up heavy metals; and e) evaluating diverse carrot germplasm for priority traits under organic management conditions in diverse environments and selecting and increasing promising populations to advance future breeding efforts.

APPROACH

Focus Area1: Cultivar development and release - Sources of germplasm and breeding approaches - At least 200 carrot breeding stocks will be preliminarily evaluated for inclusion in the CIOA2 project from Simon\'s collection. Additional materials will be added to the research materials each year based on identification of promising lines from the extensive, annual USDA winter nursery evaluations.Preliminary breeding and selection: We anticipate at least 75 populations to be under development throughout CIOA2, dropping those performing poorly each cycle and adding an equivalent number of earlier generation segregating stocks based on their performance in the winter nursery at DREC. Seed production of earlier generation stocks will be done in small (1-2m) isolation cages in WI at the WMARS.Cultivar release: Mass selection of roots from more advanced breeding populations deemed suitable for release will be grown at DREC for summer seed increase at WA (OSARF) and WI (WMARS).Focus Area 2: Variety Trials - Participatory trials and breeding: The research team will meet each winter to prioritize advanced materials for testing in the national participatory network. Comparable commercial varieties in the same market classes as the CIOA2 materials in the trials will be identified by engaging organic seed companies and farmers participating in the trial network as well as the stakeholder advisory panel.A. Project managed trials: Research station locations represent major commercial carrot production areas for large- and small-scale growers in the respective regions: the San Joaquin Valley of California, the Columbia Basin of Washington, and maritime climate of Western Washington, the Central Sands of Wisconsin, and the Ohio Valley. Variety trials of 20-30 entries that showed promise in the winter nursery or received positive evaluations from stakeholders in previous project trials will be conducted each year on certified organic sites by project trial managers, Nunez (winter trial), Hoagland, Silva, and Waters (summer trials).B. National participatory trial network: Two regional participatory evaluation sites in each of the five regions (NE, SE, Midwest, PNW, and CA) comprised of organic seed companies and organic farms will evaluate elite materials with participatory stakeholder involvement. Selection protocols will be based on trial evaluation criteria and input from the stakeholder advisory panel and

host farms to ensure a similar selection approach in each region.Focus Area 3: Understanding root microbiome interactions - Selection for nutrient management. Greenhouse trials will be conducted using 20 diverse carrot genotypes x 4 fertility rates (very low, low, medium and high) that vary in total and potentially mineralizable nutrients. Above and below ground biomass will also be analyzed with inductively coupled plasma-mass spectrometry (ICP-MS) (Perkins-Elmer, Waltham, MA) to quantify heavy metal uptake.Six genotypes with high NUE identified in the first trial will be included in a subsequent greenhouse trial to identify ideotypes that utilize enhanced root interactions with beneficial microbes to obtain nutrients using methods similar to those described in Zancarini et al., (2013b). Characterization of the active microbial community associated with carrot roots will be determined by subjecting RNA extracted from roots to RT-PCR. Plant macro- and micronutrients in above and below ground carrot tissue will be analyzed using ICP-MS.Cultivar association with arbuscular mycorrhizal fungi: To evaluate whether carrot cultivars differentially associated with varying species and strains of AMF and subsequently differ in their nutrient uptake and growth differs, trials investigating these relationships will be conducted at the Biotron Controlled Atmosphere Growth Facility (UW-Madison) as well as on the certified organic field plots at West Madison Agricultural Research Station (WMARS). Each cultivar will be inoculated with a single AMF species and strain. The species include Septoglomus deserticola, Rhizophagus intraradices, Rhizophagus clarus, and Funneliformis mosseae.Focus Area 4: Utilizing molecular markers to improve nematode resistance - Nematode resistance analyses: CIOA 2 entries will be screened for resistance to M. javanica and M. incognita each year. Entries scored as resistant or partially resistant in field screens will be re-screened in controlled inoculation tests in greenhouse pot screens with five-fold replication.Co-PD Roberts will assist the other investigators in assessing field test sites for root-knot nematode population levels and indices of root infection, using protocols described above.Development and application of gene markers: Total genomic DNA will be isolated from freeze-dried leaves, and SNP markers for six QTL developed by Parsons et al. (2015) will be mapped based on our knowledge of SNPs at the borders of QTL in the carrot genome sequence now available (Iorizzo et al., 2016).Focus Area 5: Evaluating and improving carrot flavor - Selection for carrot flavor: Initial organoleptic evaluation of the trial entries will employ slices taken at mid-root, and will be performed on all selected roots within two weeks of harvest as described by Simon (2000). Sweetness, harshness (primarily attributable to volatile terpenoids) (Senalik and Simon, 1987), and texture will be scored.A mixed model analysis of variance will be used to analyze data with taster and sample set considered random effects and variety considered fixed. Multiple Factor Analysis (MFA), an approach with a quantitative component based on distance between samples on the map and a qualitative, descriptive component, produces a consensus map interpreted using the comments and preference ratings given by the chefs.Field evaluation for foliar and seedborne diseases: Visual evaluations for foliar carrot diseases will be performed in all four organic trials in all four years of the project. Disease ratings will be taken at least three times each season at each location to monitor disease progress over time, and at an optimum time for specific soilborne diseases that might develop.Samples of seed harvested from some of the carrot entries and crosses will be tested for seedborne pathogens to screen the germplasm for entries that produce lower levels of seed infestation.Selection for carrot storage: Carrots will be placed in plastic bags with dry wood shavings, as is standard procedure to store breeding stocks (Peterson and Simon, 1986), and stored in refrigerated coolers (0.5 to 2o C) upon harvest. Postharvest storage quality will be evaluated (storage rot) on a monthly basis for 4 months postharvest.Evaluation and selection for root From each root, 2.5 g of tissue will be sampled mid-root and lyophilized. **Progress** 09/01/16 to 08/31/21 **Outputs** Target Audience:Organic and conventional vegetable growers, marketers, and consumers; vegetable seed companies; plant science researchers in horticulture, plant breeding, plant pathology, nematology, soil science, and botany Changes/Problems:Some data collection and outreach activities were delayed or omitted due to COVD restrictions What opportunities for training and professional development has the project provided?Extension activities for all years included creating new project promotion and educational materials for CIOA2, coordinating outreach and evaluation activities, presenting at multiple scientific and food industry conferences, and delivering trainings and educational events. The project communications team continued to support event outreach and track event participation and evaluation. We updated a promotional brochure that gives an overview of the project, and details about current research and research goals that was shared with growers, the carrot industry, researchers, and consumers at CIOA-related events. Each project collaborator received printed copies of the brochure to disseminate at outreach events. We also created a new scientific research poster about the project, presented at the IFOAM World Congress in September 2021 along with a proceedings paper. The IFOAM International Congress included a field tour on organic farms in France. We supplied carrot seed samples representing diverse carrot historical origins and types featured in the on-farm trial and provided an educational booklet on history and nutrition of carrot for participants. The trial entries also served as a taste testing participatory event. Trials were conducted with four organic seed company research farms - High Mowing Organic Seeds, Row 7 Seeds, Johnny's Selected Seeds, and Seed Peace/Wild Mountain Seeds. Each trial provided training on carrot trialing and seed production for employees and interns. These trials provided an opportunity for expansion of project impacts, testing materials in new regions, and soliciting input on evaluations from two organic seed companies. In late September, Colley and McKenzie delivered the OSA

Annual Field Day field day highlighting the CIOA project and the breeding and trialing work at the OSA WA Research Farm. The OSA Annual Field day was hosted virtually in September attended by over 200 participants. OSA continues to advise on and support the carrot breeding and trialing work of our colleagues at the Univ. of British Columbia as well as sharing germplasm and mentoring farmers who have expressed interest in initiating on-farm breeding projects through their exposure to the CIOA project. As part of education activities, undergraduate students, graduate students and post-doctorates are being trained in vegetable breeding, crop and seed production, disease protection and diagnosis, and soil science with a focus on organic systems as they participate in research projects critical to the COIA Project achieving the research goals. In the past year 4 graduate students projects included CIOA research activities. To inform growers and consumers about the positive environmental impact of organic production systems, and about carrot nutritional quality and flavor we continued to update and use the web site developed through eOrganic in CIOA1-2 to disseminate research updates, timely articles, and related project events (http://eorganic.info/carrotimprovement). We created two new promotion brochures giving an overview of the project, and details about current research and research goals. One brochure was tailored for and shared with growers, the carrot industry, and researchers. A second version of the brochure was developed for and shared with a general audience at CIOA-related events. We created a new scientific research poster about the project and presented it at related scientific focused events/conferences. The project reached approximately 800 growers, carrot industry members, researchers, food industry representatives, and consumers in this period. A project field sign was also created and installed at each project location field site so field visitors could clearly identify the project plots, project goals, work, partners, and funder, and visit the website for additional information. Each of the four project collaborators hosted public farmer field days in conjunction with each trial at the project research sites. Field days coincided with timing of trial evaluations. To demonstrate techniques and challenges associated with organic carrot seed production, seed increase plots were established for organic carrot seed production in two on-farm workshop. The seed increases at OSA research farm were also used in trainings on organic carrot breeding. Seed production for carrot germplasm to be released was initiated. In addition, this project is expanding graduate student and postdoc training, focused on research in organic systems and organic plant breeding. This includes one postdoc, Sahar Abdelrazek and graduate student Narda Silva at Purdue, and another postdoc, William Rolling, and graduate student Erin Lalor at UW. One visiting undergraduate scholars from Colombia (Leidy Meija, University of Caldes, Colombia) at Purdue and two graduate student scholars from Pakistan (Aneela Nijabat, University of Sargodha; Nadia Riaz, Lahore College for Women University) at UW received training by conducting research projects for their respective theses. Micaela Colley is publishing on CIOA 1 agronomic results results and CIOA 2 top growth trials as a component of her PhD thesis, data in process with plans to publish. The long-term impact of this important educational element is to establish the next generation of researchers, extension, and industry representatives with organic systems expertise. How have the results been disseminated to communities of interest?Educational events and conference presentations delivered include: Outreach: 9/17/16-9/18/16, Jefferson County Farm Tour, Chimacum, WA 9/26/2016, Organic Seed Alliance Research Farm Field Day, Chimacum, WA 11/4/16-11/6/16, CFSA Sustainable Agriculture Conference Preconference Research Intensive, Durham, NC 10/3/2016 Culinary Breeding Network Variety Showcase, Portland, OR 1/26/2017, Seed to Eaters Roundtable at EcoFarm, Pacific Grove, CA 2/2/17-2/4/17, Organicology Research Poster Session, Portland, OR 3/20/2017, CIOA2 poster and oral presentations, International Carrot Conference, Bakersfield, CA 6/29/2017, Southwest Purdue Agricultural Center Field Day, Vincennes, IN 8/7/17-8/9/17, National Association of Plant Breeders, Davis, CA 8/22/2017, Purdue Field Day at West Lafayette, West Lafayette, IN 8/24/2017, UW Madison hosted an Organic field Day at the West Madison Agricultural Research Station with good turn out from the organic seed sector. This was followed by a public Dinner and Outreach Event attended by over 200 people that evening, Madison, WI 9/7/17, Seed to Kitchen's Farm to Flavor Tasting, Madison, WI 3/13/18, Culinary Breeding Network's Variety Showcase, Oahu, HI 9/24/18, NYC Culinary Breeding Network's Variety Showcase, New York, NY 9/26/18, Seed to Kitchen's Farm to Flavor Tasting, Madison, WI 9/12/19 Seed to Kitchen's Farm to Flavor Tasting, Madison, WI Field Days and Trainings: 9/25/17 Research and Farmer Field Day, and Community Field Day and Tasting, Organic Seed Alliance Research Farm, Chimacum, WA 8/20/18 Organic Vegetable Field Day at University of Wisconsin-Madison's West Madison Agricultural Research Station, Madison, WI Participants were able to taste carrots developed through the CIOA1 project. 8/24/18 International Carrot Conference Field Tour of Carrot Research Projects, University of Wisconsin-Madison's Hancock Agricultural Research Station, Hancock, WI 8/22/19 Organic Vegetable Field Day at University of Wisconsin-Madison's West Madison Agricultural Research Station, Madison, WI Participants were able to taste carrots developed through the CIOA1 project. 9/30/19 Organic Seed Alliance Annual Field Day, OSA Research Farm, Chimacum, WA. Farmers and public were able to taste carrots and participate in making selections in breeding populations. 9/12/2019 Seed to Kitchen's Farm to Flavor Madison, WI 300 9/22/2019 Jefferson County Farm Tour Chimacum, WA 50 9/30/2019 5th Annual OSA Fall Field Day Chimacum, WA 120 2/12/20-2/15/20 Organic Seed Growers Conference Corvallis, OR 450 2/16/2020 CBN Variety Showcase Portland, OR 500 3/10/2021 CIOA/SCRI Carrot Harvest Public Field Day El Centro, CA45 Meetings: Simon, P. OREI PD Meeting,

Washington, D.C.10/17-18/18 Colley, M, L. McKenzie, and P. Simon Organic Seed Growers Conference, Corvallis, OR 2/14-17/18 Silva, E. MOSES Organic Farming Conference, La Crosse, WI 2/22-24/18 Simon, P. ASHS, Washington, D.C.7/31 - 8/3/18 Simon, P. NAPB, Guelph, Ontario, Canada 8/7-10/18 Hoagland, L. Purdue Student Farm Field Day, West Lafayette, IN 8/20/18 All PIs, 39th Int'l. Carrot Conference, Madison, WI 8/22-24/18 Trivino, N. T. Combining pre-treatment of carrot roots (Daucus carota) with novel primer sets for better bacterial endophyte community characterization. HLA Research & Design Retreat, Layafette,IN May 8th-2019. Abdelrazek, S. and L.A Hoagland. Transmission and functional role of carrot endophyte communities. American Phytopathological Society (APS). Annual Meeting Cleveland, OH. Aug 3-8, 2019, (Oral) Abdelrazek, S and L.A Hoagland. Dynamics of endophyte communities associated with carrot. APS Annual Meeting , Cleveland, OH. Aug 3-8, 2019 (Poster). Hoagland, L. Characterizing carrot microbiomes and their potential role in plant and human health. North Central Region Plant Germplasm Repository Meeting, On-line, 2020. Dawson, J.C. Participatory Trialing for Direct-Market Vegetable Growers in the Upper Midwest. Washington State University Crop Science Seminar. Pullman, WA Jan 10, 2020. Dawson, J.C. Participatory Trialing for Direct-Market Vegetable Growers in the Upper Midwest. Michigan State University Horticulture and Plant, Soil and Microbial Sciences Seminar. East Lansing, MI, Jan 19, 2020. Simon, P. et al. Carrot Improvement for Organic Agriculture and Consumer Value. International Federation of Organic Agriculture Movements World Congress. September 6-10, 2021. Blogposts Seed Broadcast, \"Getting Creative in the Kitchen with Chromatic Carrots\", 10/13/16 Seed Broadcast, \"Working Around the Calendar to Breed Organic Carrots\", 3/10/17 Seed Broadcast, \"This Weekend's Menu: Roasted Carrot Bolognese\", 6/2/17 Seed Broadcast, \"Join Us: Organic Seed Training in Indiana\", 6/14/17 Seed Broadcast, \"Evaluating the Fruits of Our Labor\", 8/23/17 Seed Broadcast, \"Join Us for Our Community Field Day and Tasting\", 9/6/17 Seed Broadcast, \"Business Member Spotlight: High Mowing Organic Seeds,\" https://seedalliance.org/2017/business-member-spotlight-high-mowing-organic-seeds/ Seed Broadcast, \"Supporting Hawaii's Growing Seed Movement,\" https://seedalliance.org/2018/novic-team-brings-on-farm-training-to-hawaii/ Seed Broadcast, \"Carrot Breeders Find Promising Results at Winter Nursery,\" https://seedalliance.org/2018/carrot-breeders-find-promising-results-at-the-winter-nursery-harvest/ Seed Broadcast, \"Organic Carrot Breeding Intensive in Washington,\" https://seedalliance.org/2018/organic-carrot-breeding-intensive-washington-october/ Seed Broadcast, \"'Glean & Clean' Proves to be a Bushel of Fun,\" https://seedalliance.org/2018/a-bushel-of-fun/ Seed Broadcast, \"Organic Carrot Trials and Tastings in New York,\" https://seedalliance.org/2018/carrot-trials-and-tastings-in-new-york/ OSA Blog, Farm to Flavor: Culinary Breeding in Carrots, 10/30/19,https://seedalliance.org/2019/farm-to-flavor-culinary-breeding-in-carrots/ OSA Blog, Breeding Carrots with Partners to Address Diverse Needs, 3/30/20,https://seedalliance.org/2020/cioa-ca-harvest2020/ Produce Grower, Soil microbiome can improve carrot resistance to deadly fungus, 7/22/20https://www.producegrower.com/article/carrots-greenhouse-study-purdue/ What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? This project addresses the critical needs of organic carrot producers by developing orange and novel colored carrots with improved disease and nematode resistance, improved weed competitiveness, and improved nutritional value and flavor. About 100,000 acres of carrots are grown annually in the U.S. The 2014 Census of Agriculture, estimated 14% of this carrot production is in organic systems, vs. 3% for vegetable crops overall. Organic production of carrots has significant pest and disease challenges. Over 80% of the U.S. carrot production land is infested with one or more species of root-knot nematodes. Alternaria leaf blight (ALB), other foliar diseases and cavity spot are major carrot diseases in virtually all production areas of the world. The needs for effective non-chemical methods of pest and disease control to the future of the US organic vegetable production are urgent. Carrots are among the slowest crops for growers to establish, often making weed control the most expensive cost of organic production. Flavor and nutritional value are the most important characteristics noted by consumers of organic foods and novel colors attract carrot consumers. This project is developing novel carrots improved for nutrition and flavor, integrated with critical pest and disease resistance and vigorous growth. This project also expands our understanding of root-microbiome interactions critical for growth and nutrient uptake of organically-grown carrots. Goals and annual progress: Long-term goals of this project are to: 1) deliver carrot cultivars with improved disease and nematode resistance, improved nutrient acquisition, seedling vigor and weed competitive traits, increased marketable yield, superior nutritional value, flavor and other culinary qualities, and storage quality for organic production; 2) determine how carrot genotypes interact with/influence, the root microbiome to access key nutrients under limiting environments and avoid heavy metal uptake; 3) inform growers about cultivar performance to maximize organic carrot production, markets, and organic seed usage; 4) inform consumers about the positive environmental impact of organic production systems and about carrot nutritional quality, flavor and culinary attributes; and 5) train students in critical organic agriculture issues. Primary activities: Focus Area 1: Cultivar development and release New breeding populations (\~250) were developed during this project. Continued advancement was done on nine orange breeding populations with improved flavor, carotene content, ALB and cavity spot resistance. Seven purple breeding populations with improved flavor, texture, and robust agronomic production qualities were also advanced. Four new breeding populations were started . Successful production of seed to increase stock of novel colored populations slated for release was

accomplished. Advanced selections were trialed by five organic seed companies and formal release is underway for three populations from CIOA1 (R6636, R6220, Y1246). Commercial release plans are underway for release of the newly named 'Carnelian' red carrot variety (R6636) with High Mowing Organic Seeds. Focus Area 2: Variety trials on research stations and national participatory sites Variety trials were held in WI, WA, and CA with participatory sites in OR, CO, VA, NY, ME, and VT. Included were 12 advanced breeding populations, check varieties, and selections from among 127 promising breeding populations. Flavor, marketability, productivity, pigment content and storage quality of selected CIOA entries was completed. Advanced lines were distributed to on-farm trials over two seasons as part of the Seed to Kitchen Collaborative trials in the upper Midwest. Focus Area 3: Advancing research on root microbiome interactions A study to determine whether 4 carrot cultivars preferentially recruit AMF communities under organic management was carried out on five organic vegetable farms and the University of Wisconsin (UW) Research Station. Mean root colonization was significantly greater for one open pollinated variety which aligns with previous research where modern varieties of several crops demonstrate a loss of response to colonization by AMF to suggest that screening diverse genotypes may identify enhanced AMF colonization, to be used either directly be farmers or to be included in breeding programs. Interesting interactions in the role of AMF in increasing soil proteins in more highly disturbed environments were suggested. This can be characteristic of organic farms with their reliance on tillage and cultivation. Carrot taproots grown in a field trial comparing organic and conventional management were colonized by an abundant and diverse assortment of bacteria and fungi, though endophytes were more diverse and had greater antagonistic activity against A. dauci that causes ALB in the organic system. Carrot genotype also affected endophyte abundance in taproots and potential for individual isolates to affect seed germination, seedling growth and ALB tolerance. Carrots vertically transmit endophytic microbes within their seeds. These microbes play an important role in germination and early seedling performance and appear to be part of a core carrot microbiome. Carrot genotypes also vary in their potential to promote organic matter priming to scavenge nitrogen, tolerate cadmium (Cd) stress, and accumulate Cd in taproots. The composition of AMF communities present in soil also plays a major role in mediating micronutrient/heavy metal uptake. Carrot genotypes also vary in their potential to alter soil microbial communities that influence susceptibility to pathogenic nematodes in subsequent generations, and N fertility management influences these relationships. Results of these studies demonstrate that carrot productivity is intimately connected to root microbiomes. Soil management practices are critical in promoting beneficial carrot-soil-microbial relationships, though genotype also plays a role indicating that with further work it will be possible to select for these relationships. Focus Area 4: Utilizing molecular markers to improve nematode resistance CIOA2 advanced experimental selections and promising selections were included in field trialing for all 5 years at fields in CA with the prevalent root-knot nematode, M. incognita. Greenhouse tests were used to provide highly controlled screening conditions. Carrot selections were advanced for seed production to be included in genetic analysis, molecular marker evaluation, and breeding line development. Molecular marker evaluation found a major M. hapla resistance gene on chromosome 9 which was fine-mapped to develop markers for breeders. Resistance traits for M. hapla, M. incognita, M. arenaria and M. javanica were identified and confirmed in multiple greenhouse screenings Foliar diseases were diagnosed. Motley dwarf was identified for 3 years in western WA trials, and also in central WA. ALB resistance was evaluated in central WI where 34 promising CIOA2 selections were identified where infection was high and wide variation in resistance was observed. Cavity spot resistance was tested for advanced CIOA2 breeding selections in infested fields in CA and WA and 4 selections advanced for breeding. Focus Area 5: Evaluating and improving carrot flavor, nutritional, and postharvest quality CIOA varieties varied in appearance, texture, sweetness and harshness. Overall flavor was rated on all samples and was positively correlated with sweetness but negatively correlated with harshness. Flavor was rated on all samples each year of trials. Nutritional carotenoids and anthocyanins were evaluated for all advanced breeding lines. CIOA varieties slated for release were evaluated for flavor by chefs in 2019. Public educational events featured diverse advanced varieties at two virtual OSA WA research farm field day. and the Farm to Flavor event in Madison, WI (300+ attendees) in 2019. **Publications** - Type: Theses/Dissertations Status: Published Year Published: 2020 Citation: Narda Silva (MS) Characterizing carrot microbiomes and their potential role in soil organic matter decomposition. M.S. Thesis, Purdue University. 114p - Type: Theses/Dissertations Status: Submitted Year Published: 2021 Citation: Erin Lalor (MS) Variation of mineral element accumulation in a diverse carrot germplasm collection. M.S. Thesis, University of Wisconsin - Madison. 207p - Type: Theses/Dissertations Status: Submitted Year Published: 2021 Citation: Kevser Ozel (MS) Identification and Genetic Mapping of New Sources of Nematode Resistance in Carrot (Daucus carota L.) M.S. Thesis, University of Wisconsin - Madison. 154p - Type: Theses/Dissertations Status: Submitted Year Published: 2020 Citation: Leidy Meija (BS) Carrot genotype and nitrogen stress alter plant soil feedbacks and susceptibly to pathogenic nematodes BS Thesis, Purdue University - Type: Theses/Dissertations Status: Submitted Year Published: 2021 Citation: Hannah Komanapalli (BS) Carrot AMF elements. BS Thesis, Purdue University - Type: Journal Articles Status: Published Year Published: 2017 Citation: Simon, P.W., Zystro, J, Roberts, P.A., Waters, T., Colquhoun, J., Navazio, J., Colley, M., McCluskey, C., Hoagland, L., duToit, L., Silva, E., Nunez, J. The CIOA (Carrot Improvement for Organic Agriculture) Project: Location, cropping system, and genetic background influence carrot performance

including top height and flavor. Acta Hort.1153: 1-8. 2017. - Type: Journal Articles Status: Published Year Published: 2017 Citation: Arbizu, C.I., P.Tas, P.W. Simon, D.M. Spooner Phylogenetic prediction of carrot leaf blight resistance in wild and cultivated species of carrots. Crop Sci. 57:2645-2653. 2017. - Type: Journal Articles Status: Published Year Published: 2018 Citation: Turner, S.D., P.L. Maurizio, W. Valdar, B.S. Yandell, and P.W. Simon. Dissecting the genetic architecture of shoot growth in carrot (Daucus carota L.) using a diallel mating design. G3 8:411-426. 2018. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Keller-Pearson, M., Yang Liu, A. Peterson, K.Pederson, L. Willems, J.-M. An&#65533;, E.M. Silva. 2020. Inoculation with arbuscular mycorrhizal fungi has a more significant positive impact on the growth of open-pollinated heirloom varieties of carrots than on hybrid cultivars under organic management conditions. Agriculture, Ecosystems & Environment 289: 15. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Abdelrazek, S., Simon, P., Colley, M., Mengiste, T., Sulba, Jyothi *Hoagland, L., 2020. Changes in the core endophytic mycobiome of carrot taproots in response to crop management and genotype Scientific Reports doi.org/10.1038/s41598-020-70683-x. Journal impact factor: 4.576 - Type: Journal Articles Status: Published Year Published: 2020 Citation: Abdelrazek, S., Simon, P., Colley, M., Mengiste, T., *Hoagland, L., 2020. Crop management system and carrot genotype affect endophyte composition and Alternaria dauci suppression. PLOSOne doi.org/10.1371/journal.pone.0233783. Journal impact factor: 3.226

PROGRESS

2019/09 TO 2020/08 Target Audience:Organic and conventional vegetable growers, marketers, and consumers; vegetable seed companies; plant science researchers in horticulture, plant breeding, plant pathology, nematology, soil science, and botany. Changes/Problems:Some data collection and outreach activities were delayed or omitted due to COVD restrictions What opportunities for training and professional development has the project provided?Year 4 extension activities included creating new project promotion and educational materials for CIOA2, coordinating outreach and evaluation activities, presenting at multiple scientific and food industry conferences, and delivering trainings and educational events. The project communications team continued to support event outreach and track event participation and evaluation. We updated a promotional brochure that gives an overview of the project, and details about current research and research goals that was shared with growers, the carrot industry, researchers, and consumers at CIOA-related events. Each project collaborator received printed copies of the brochure to disseminate at outreach events. We also created a new scientific research poster about the project and presented it at related scientific focused events/conferences. Trials were conducted with six organic seed company research farms - High Mowing Organic Seeds, Adaptive Seeds, Commonwealth Seeds, Row 7 Seeds, Johnny\'s Selected Seeds, and Seed rEvolution Now!. Each trial provided training on carrot trialing and seed production for employees and interns. These trials provided an opportunity for expansion of project impacts, testing materials in new regions, and soliciting input on evaluations from two organic seed companies. In late September, Colley and McKenzie delivered the OSA Annual Field Day field day highlighting the CIOA project and the breeding and trialing work at the OSA WA Research Farm. The OSA Annual Field day was attended by over approximately two dozen farmers, farmer-breeders and seed company representatives, and 100 members of the public. OSA continues to advise on and support the carrot breeding and trialing work of our colleagues at the Univ. of British Columbia as well as sharing germplasm and mentoring farmers who have expressed interest in initiating on-farm breeding projects through their exposure to the CIOA project. As part of education activities, undergraduate students, graduate students and post-doctorates are being trained in vegetable breeding, crop and seed production, disease protection and diagnosis, and soil science with a focus on organic systems as they participate in research projects critical to the COIA Project achieving the research goals. In the past year 4 graduate students projects included CIOA research activities. To inform growers and consumers about the positive environmental impact of organic production systems, and about carrot nutritional quality and flavor we continued to update and use the web site developed through eOrganic in CIOA1 to disseminate research updates, timely articles, and related project events (http://eorganic.info/carrotimprovement). We created two new promotion brochures giving an overview of the project, and details about current research and research goals. One brochure was tailored for and shared with growers, the carrot industry, and researchers. A second version of the brochure was developed for and shared with a general audience at CIOA-related events. We created a new scientific research poster about the project and presented it at related scientific focused events/conferences. The project reached approximately 800 growers, carrot industry members, researchers, food industry representatives, and consumers in this period. A project field sign was also created and installed at each project location field site so field visitors could clearly identify the project plots, project goals, work, partners, and funder, and visit the website for additional information. Each of the four project collaborators hosted public farmer field days in conjunction with each trial at the project research sites. Field days coincided with timing of trial evaluations. In addition, this project is expanding graduate student and postdoc training, focused on research in organic systems and organic plant breeding. This includes one postdoc, Sahar Abdelrazek and graduate student Narda Silva at Purdue, and another postdoc, William

Rolling, and graduate student Erin Lalor at UW. One visiting undergraduate scholars from Colombia (Leidy Meija, University of Caldes, Colombia) at Purdue and two graduate student scholars from Pakistan (Aneela Nijabat, University of Sargodha; Nadia Riaz, Lahore College for Women University) at UW received training by conducting research projects for their respective theses. Micaela Colley is publishing on CIOA 1 agronomic results results and CIOA 2 top growth trials as a component of her PhD thesis, data in process with plans to publish in 2021. The long-term impact of this important educational element is to establish the next generation of researchers, extension, and industry representatives with organic systems expertise. How have the results been disseminated to communities of interest?Educational events and conference presentations delivered include: Outreach: September 12, 2019 Seed to Kitchen\'s Farm to Flavor Tasting, Madison, WI Field Days and Trainings: 9/30/19 Organic Seed Alliance Annual Field Day, OSA Research Farm, Chimacum, WA. Farmers and public were able to taste carrots and participate in making selections in breeding populations. 9/12/2019 Seed to Kitchen\'s Farm to Flavor Madison, WI 300 9/22/2019 Jefferson County Farm Tour Chimacum, WA 50 9/30/2019 5th Annual OSA Fall Field Day Chimacum, WA 120 2/12/20-2/15/20 Organic Seed Growers Conference Corvallis, OR 450 2/16/2020 CBN Variety Showcase Portland, OR 500 3/10/2020 CIOA/SCRI Carrot Harvest Public Field Day El Centro, CA 2020 Organic Vegetable Field Day at University of Wisconsin-Madison, Purdue University, University of California - Riverside, and California Agriculture Extension were cancelled due to COVID Meetings: Hoagland, L. Characterizing carrot microbiomes and their potential role in plant and human health. North Central Region Plant Germplasm Repository Meeting, On-line, 2020. Dawson, J.C. Participatory Trialing for Direct-Market Vegetable Growers in the Upper Midwest.Washington State University Crop Science Seminar. Pullman, WA Jan 10, 2020. Dawson, J.C. Participatory Trialing for Direct-Market Vegetable Growers in the Upper Midwest.Michigan State University Horticulture and Plant, Soil and Microbial Sciences Seminar. East Lansing, MI, Jan 19, 2020. Blogposts OSA Blog, Farm to Flavor: Culinary Breeding in Carrots, 10/30/19,https://seedalliance.org/2019/farm-to-flavor-culinary-breeding-in-carr ots/ OSA Blog, Breeding Carrots with Partners to Address Diverse Needs, 3/30/20,https://seedalliance.org/2020/cioa-ca-harvest2020/ Produce Grower, Soil microbiome can improve carrot resistance to deadly fungus, 7/22/20https://www.producegrower.com/article/carrots-greenhouse-study-purdue/ What do you plan to do during the next reporting period to accomplish the goals?Selected field trialing and research activities described for Year 1-4 will continue in Year 5 - namely the winter 2020-21 winter root nursery is underway to produce stecklings to increase seed supplies of CIOA germplasm, especially breeding lines staged for release. In addition, seed increase of promising genetic stocks included in trials will be continued and resistance testing of ALB in WI and nematode resistance in CA will be continued in 2021. Marker work for nematode resistance will continue, and data will be summarized published. Future educational events planned for Year 5: Presentations on breeding for organic ag and the CIOA2 project may be delivered at selected regional vegetable growers meetings including the Pacific Northwest Vegetable Meeting; Seed Sovereignty Field Day/NOFA; Great Lakes Fruit, Vegetable, and Farm Market Expo; Midwestern Organic and Sustainable Education Service (MOSES) Conference which are being held virtually.

2018/09 TO 2019/08 Target Audience:Organic and conventional vegetable growers, marketers, and consumers; vegetable seed companies; plant science researchers in horticulture, plant breeding, plant pathology, nematology, soil science, and botany Changes/Problems:A no-cost project extension of one additional year will be requested. What opportunities for training and professional development has the project provided?Year 3 extension activities included creating new project promotion and educational materials for CIOA2, coordinating outreach and evaluation activities, presenting at multiple scientific and food industry conferences, and delivering trainings and educational events. The project communications team continued to support event outreach and track event participation and evaluation. We created a new promotional brochure giving an overview of the project, and details about current research and research goals that was shared with growers, the carrot industry, researchers, and consumers at CIOA-related events. Each project collaborator received printed copies of the brochure to disseminate at outreach events. We also created a new scientific research poster about the project and presented it at related scientific focused events/conferences. Replicated trials were conducted on two organic seed company research farms in the NE and SE (High Mowing Organic Seed and Southern Exposure Seed Exchange) and they provided training on carrot trialing and seed production. These two trials provided an opportunity for expansion of project impacts, testing materials in new regions, and soliciting input on evaluations from two organic seed companies. Fall, 2019, Colley and McKenzie delivered a field day and workshop on organic carrot plant breeding at the OSA research farm in WA with over two dozen farmer-breeders and seed company representatives present. Several participants expressed interest in initiating on-farm breeding projects and the CIOA team plans to support these efforts by advising and sharing of germplasm. As part of education activities, undergraduate students, graduate students and post-doctorates are being trained in vegetable breeding, crop and seed production, disease protection and diagnosis, and soil science with a focus on organic systems as they participate in research projects critical to the COIA Project achieving the research goals. In the past year 4 graduate students projects included CIOA research activities. To inform growers and consumers

about the positive environmental impact of organic production systems, and about carrot nutritional quality and flavor we continued to update and use the web site developed through eOrganic in CIOA I to disseminate research updates, timely articles, and related project events (http://eorganic.info/carrotimprovement). We created two new promotion brochures giving an overview of the project, and details about current research and research goals. One brochure was tailored for and shared with growers, the carrot industry, and researchers. A second version of the brochure was developed for and shared with a general audience at CIOA-related events. We created a new scientific research poster about the project and presented it at related scientific focused events/conferences. The project reached approximately 800 growers, carrot industry members, researchers, food industry representatives, and consumers in this period. A project field sign was also created and installed at each project location field site so field visitors could clearly identify the project plots, project goals, work, partners, and funder, and visit the website for additional information. Each of the four project collaborators hosted public farmer field days in conjunction with each trial at the project research sites. Field days coincided with timing of trial evaluations. To demonstrate techniques and challenges associated with organic carrot seed production, seed increase plots were established for organic carrot seed production in two on-farm workshop. The seed increases at OSA research farm were also used in trainings on organic carrot breeding. Seed production for carrot germplasm to be released was initiated. In addition, this project is expanding graduate student training, focused on research in organic systems and organic plant breeding. One student, Sahar Abdelrazk, completed her PhD in December 2018, and another graduate student, Narda Silva, is preparing to graduate with her MS in May 2019. Two visiting undergraduate scholars from Latin America received training by conducting research projects for their senior theses. One, Gabriella Santos (Zamorano University, Honduras) completed a project in spring 2018, and another, Leidy Mejas (University of Caldes, Colombia) is currently conducting an experiment. Finally, an undergraduate student at Purdue, Hannah Komanapelli, is currently conducted a project as part of her honors thesis. The long-term impact of this important educational element is to establish the next generation of researchers, extension, and industry representatives with organic systems expertise. How have the results been disseminated to communities of interest?Educational events and conference presentations delivered include: Outreach: September 12, 2019 Seed to Kitchen\'s Farm to Flavor Tasting, Madison, WI Field Days and Trainings: August 22, 2019 Organic Vegetable Field Day at University of Wisconsin-Madison\'s West Madison Agricultural Research Station, Madison, WI Participants were able to taste carrots developed through the CIOA1 project. Meetings: Trivino, N. T. Combining pre-treatment of carrot roots (Daucus carota) with novel primer sets for better bacterial endophyte community characterization. HLA Research & Design Retreat, May 8th-2019. Layafette,IN Abdelrazek, S. and L.A Hoagland. Transmission and functional role of carrot endophyte communities. American Phytopathological Society (APS). Annual Meeting Aug 3-8, 2019, Cleveland, OH. (Oral) Abdelrazek, S and L.A Hoagland. Dynamics of endophyte communities associated with carrot. APS Annual Meeting Aug 3-8, 2019, Cleveland, OH. (Poster). Blogposts Seed Broadcast, \"Business Member Spotlight: High Mowing Organic Seeds,\" https://seedalliance.org/2017/business-member-spotlight-high-mowing-organic-see ds/ Seed Broadcast, \"Supporting Hawaii\'s Growing Seed Movement,\" https://seedalliance.org/2018/novic-team-brings-on-farm-training-to-hawaii/ Seed Broadcast, \"Carrot Breeders Find Promising Results at Winter Nursery,\" https://seedalliance.org/2018/carrot-breeders-find-promising-results-at-the-win ter-nursery-harvest/ Seed Broadcast, \"Organic Carrot Breeding Intensive in Washington,\" https://seedalliance.org/2018/organic-carrot-breeding-intensive-washington-octo ber/ Seed Broadcast, \"\'Glean & Clean\' Proves to be a Bushel of Fun,\" https://seedalliance.org/2018/a-bushel-of-fun/ Seed Broadcast, \"Organic Carrot Trials and Tastings in New York,\" https://seedalliance.org/2018/carrot-trials-and-tastings-in-new-york/ What do you plan to do during the next reporting period to accomplish the goals?All field trialing and research activities described for Year 1-3 will continue in Year 4. In addition, seed increase of promising genetic stocks included in trials will be continued and expanded. Future educational events planned for Year 4: Presentations on breeding for organic and the CIOA2 project will be delivered at selected regional vegetable growers meetings including the Pacific Northwest Vegetable Meeting, Kennewick, WA; Seed Sovereignty Field Day/NOFA, Dartmouth, MA; Great Lakes Fruit, Vegetable, and Farm Market Expo, Grand Rapids, MI; Organic Seed Growers Conference, Corvallis, OR; Organicology Conference, Portland, OR; Organic Agriculture Research Symposium; Midwestern Organic and Sustainable Education Service (MOSES) Conference, LaCrosse, WI; ASHS, Orlando. The project team holds an annual planning meeting in conjunction with the Organic Agriculture Research Symposium.

2017/09 TO 2018/08 Target Audience: Organic and conventional vegetable growers, marketers, and consumers; vegetable seed companies; plant science researchers in horticulture, plant breeding, plant pathology, nematology, soil science, botany Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Year 2 extension activities included creating new project promotion and educational materials for CIOA2, coordinating outreach and evaluation activities, presenting at multiple scientific and food industry conferences, and delivering trainings and educational events. The project communications team continued to support event outreach and track event participation and evaluation. We created a new promotional brochure giving an overview of the project, and details about current research and

research goals that was shared with growers, the carrot industry, researchers, and consumers at CIOA-related events. Each project collaborator received printed copies of the brochure to disseminate at outreach events. We also created a new scientific research poster about the project and presented it at related scientific focused events/conferences. Replicated trials were conducted on two organic seed company research farms in the NE and SE (High Mowing Organic Seed and Southern Exposure Seed Exchange) and they provided training on carrot trailing and seed production. These two trials provided an opportunity for expansion of project impacts, testing materials in new regions, and soliciting input on evaluations from two organic seed companies. An on-farm trial was also conducted in Hawaii at Counter Culture Farm on Oahu. This trial added a tropical environment for testing material and one of the CIOA entries (Brasilia) performed well. Fall, 2018, Simon, Colley and McKenzie delivered a workshop on organic carrot plant breeding at the OSA research farm in WA with over a dozen farmer-breeders and seed company representatives present. Several participants expressed interest in initiating on-farm breeding projects in 2019 and the CIOA team plans to support these efforts by advising and sharing of germplasm. As part of education activities, undergraduate students, graduate students and post-doctorates are being trained in vegetable breeding, crop and seed production, disease protection and diagnosis, and soil science with a focus on organic systems as they participate in research projects critical to the COIA Project achieving the research goals. In the past year 4 graduate students projects included CIOA research activities. To inform growers and consumers about the positive environmental impact of organic production systems, and about carrot nutritional quality and flavor we continued to update and use the web site developed through eOrganic in CIOA I to disseminate research updates, timely articles, and related project events (http://eorganic.info/carrotimprovement). We created two new promotion brochures giving an overview of the project, and details about current research and research goals. One brochure was tailored for and shared with growers, the carrot industry, and researchers. A second version of the brochure was developed for and shared with a general audience at CIOA-related events. We created a new scientific research poster about the project and presented it at related scientific focused events/conferences. The project reached approximately 800 growers, carrot industry members, researchers, food industry representatives, and consumers in this period. A project field sign was also created and installed at each project location field site so field visitors could clearly identify the project plots, project goals, work, partners, and funder, and visit the website for additional information. Each of the four project collaborators hosted public farmer field days in conjunction with each trial at the project research sites. Field days coincided with timing of trial evaluations. To demonstrate techniques and challenges associated with organic carrot seed production, seed increase plots were established for organic carrot seed production in two on-farm workshop. The seed increases at OSA research farm were also used in trainings on organic carrot breeding. . Seed production for carrot germplasm to be released was initiated. In addition, this project is expanding graduate student training, focused on research in organic systems and organic plant breeding. The long-term impact of this important educational element is to establish the next generation of researchers, extension, and industry representatives with organic systems expertise. How have the results been disseminated to communities of interest?Educational events and conference presentations delivered in 2017-2018 include: Outreach: September 7, 2017, Seed to Kitchen\'s Farm to Flavor Tasting, Madison, WI March 13, 2018, Culinary Breeding Network\'s Variety Showcase, Oahu, HI September 24, 2018, NYC Culinary Breeding Network\'s Variety Showcase, New York, NY September 26, 2018, Seed to Kitchen\'s Farm to Flavor Tasting, Madison, WI Field Days and Trainings: September 25, 2017, Research and Farmer Field Day, and Community Field Day and Tasting, Organic Seed Alliance Research Farm, Chimacum, WA August 20, 2018, Organic Vegetable Field Day at University of Wisconsin-Madison\'s West Madison Agricultural Research Station, Madison, WI Participants were able to taste carrots developed through the CIOA1 project. August 24, 2018, International Carrot Conference Field Tour of Carrot Research Projects, University of Wisconsin-Madison\'s Hancock Agricultural Research Station, Hancock, WI Meetings: October 17-18, 2018, OREI PD Meeting, Washington, D.C. February 14-17, 2018, Organic Seed Growers Conference, Corvallis, OR February 22-24, 2018, MOSES Organic Farming Conference, La Crosse, WI July 31-August 3, 2018, ASHS, Washington, D.C. August 7-10, 2018, NAPB, Guelph, Ontario, Canada August 20, 2018, Purdue Student Farm Field Day, West Lafayette, IN August 22-24, 2018 39th Int\'l. Carrot Conference, Madison, WI Upcoming: September 11, 2018, Fundamentals of Organic Plant Breeding Intensive and Field Day, Mineral, VA September 19-22, 2018, Apiaceae Meeting, Krakow, Poland September 22, 2018, Seed Saving and Variety Improvement Workshop, Shelter Island, NY September 26, 2018, Farm to Flavor, a public dinner and outreach event attended by about 330 people in, Madison, WI featuring dishes by participating chefs. Carrots from the CIOA project were one of the featured varieties and attendees received information about the project October 1, 2018, Research and Farmer Field Day, and Community Field Day and Tasting, Organic Seed Alliance Research Farm, Chimacum, WA October 9, 2018, Organic Carrot Breeding Workshop, Organic Seed Alliance Research Farm, Chimacum, WA November 15-16, 2018, Pacific Northwest Vegetable Association Meeting, Washington February 14-16, 2019, Organicology, Portland, OR Blogposts Seed Broadcast, \"Business Member Spotlight: High Mowing Organic Seeds,\" 9/28/17, https://seedalliance.org/2017/business-member-spotlight-high-mowing-organic-see ds/ Seed Broadcast, \"Supporting Hawaii\'s Growing Seed Movement,\" 3/22/18, Seed Broadcast, \"Carrot Breeders Find Promising

Results at Winter Nursery,\" 3/22/18, Seed Broadcast, \"Organic Carrot Breeding Intensive in Washington,\" 9/14/18, Seed Broadcast, \"\'Glean & Clean\' Proves to be a Bushel of Fun,\" 10/17/18, Seed Broadcast, \"Organic Carrot Trials and Tastings in New York,\" 10/26/18, https://seedalliance.org/2018/carrot-trials-and-tastings-in-new-york/ What do you plan to do during the next reporting period to accomplish the goals?All field trialing and research activities described for Year 1-2 will continue in Year 3. In addition, seed increase of promising genetic stocks included in trials will be continued and expanded. Future educational events planned for Year 3: Presentations on breeding for organic and the CIOA2 project will be delivered at selected regional vegetable growers meetings including the Pacific Northwest Vegetable Meeting, Kennewick, WA (Q4, 2018); Seed Sovereignty Field Day/NOFA, Dartmouth, MA; Great Lakes Fruit, Vegetable, and Farm Market Expo, Grand Rapids, MI; Organic Seed Growers Conference, Corvallis, OR; Organicology Conference, Portland, OR; Organic Agriculture Research Symposium; Midwestern Organic and Sustainable Education Service (MOSES) Conference, LaCrosse, WI; ASHS, Las Vegas. The project team holds an annual planning meeting in conjunction with the Organic Agriculture Research Symposium.

2016/09 TO 2017/08 Target Audience: Organic and conventional vegetable growers, marketers, and consumers; vegetable seed companies; plant science researchers in horticulture, plant breeding, plant pathology, nematology, soil science, botany Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Year 1 extension activities included creating new project promotion and educational materials for CIOA2, coordinating outreach and evaluation activities, presenting at multiple scientific and food industry conferences, and delivering trainings and educational events. The project communications team continued to support event outreach and track event participation and evaluation. We created a new promotional brochure giving an overview of the project, and details about current research and research goals that was shared with growers, the carrot industry, researchers, and consumers at CIOA-related events. Each project collaborator received printed copies of the brochure to disseminate at outreach events. We also created a new scientific research poster about the project and presented it at related scientific focused events/conferences. Replicated trials were conducted on two organic seed company research farms in the NE and SE (High Mowing Organic Seed and Southern Exposure Seed Exchange) and they provided training on carrot trailing and seed production. These two trials provided an opportunity for expansion of project impacts, testing materials in new regions, and soliciting input on evaluations from two organic seed companies. As part of education activities, undergraduate students, graduate students and post-doctorates are being trained in vegetable breeding, crop and seed production, disease protection and diagnosis, and soil science with a focus on organic systems as they participate in research projects critical to the COIA Project achieving the research goals. Collaborators hosted public farmer field days in conjunction with each trial. Field days coincided with timing of trial evaluations. To inform growers and consumers about the positive environmental impact of organic production systems, and about carrot nutritional quality and flavor we continued to update and use the web site developed through eOrganic in CIOA I to disseminate research updates, timely articles, and related project events (http://eorganic.info/carrotimprovement). We created a new promotion brochure giving an overview of the project, and details about current research and research goals that was shared with growers, the carrot industry, researchers, and consumers at CIOA-related events. Additionally, we created a new scientific research poster about the project and presented it at related scientific focused events/conferences. The project reached approximately 800 growers, carrot industry members, researchers, food industry representatives, and consumers in this period. A project field sign was also created and installed at each project location field site so field visitors could clearly identify the project plots and visit the website for additional information. To demonstrate techniques and challenges associated with organic carrot seed production, seed increase plots were established for organic carrot seed production in two on-farm workshops. Seed production for carrot germplasm to be released was initiated. In addition, this project is expanding graduate student training, focused on research in organic systems and organic plant breeding. The long-term impact of this important educational element is to establish the next generation of researchers, extension, and industry representatives with organic systems expertise. How have the results been disseminated to communities of interest?Educational events and conference presentations delivered in 2016-2017 include: 9/17/16-9/18/16, Jefferson County Farm Tour, Chimacum, WA 9/26/2016, Organic Seed Alliance Research Farm Field Day, Chimacum, WA 11/4/16-11/6/16, CFSA Sustainable Agriculture Conference Preconference ResearchIntensive, Durham, NC 10/3/2016 Culinary Breeding Network Variety Showcase, Portland, OR 1/26/2017, Seed to Eaters Roundtable at EcoFarm, Pacific Grove, CA 2/2/17-2/4/17, Organicology Research Poster Session, Portland, OR 3/20/2017, CIOA2 poster and oral presentations, International Carrot Conference, Bakersfield, CA 6/29/2017, Southwest Purdue Agricultural Center Field Day, Vincennes, IN 8/7/17-8/9/17, National Association of Plant Breeders, Davis, CA 8/22/2017, Purdue Field Day at West Lafayette, West Lafayette, IN 8/24/2017, UW Madison hosted an Organic field Day at the West Madison Agricultural Research Station with good turn out from the organic seed sector. This was followed by a public Dinner and Outreach Event attended by over 200 people that evening, Madison, WI Blogposts Seed Broadcast, \"Getting Creative in the Kitchen with Chromatic Carrots\", 10/13/16 Seed Broadcast, \"Working Around the Calendar to Breed Organic

Carrots\", 3/10/17 Seed Broadcast, \"This Weekend\'s Menu: Roasted Carrot Bolognese\", 6/2/17 Seed Broadcast, \"Join Us: Organic Seed Training in Indiana\", 6/14/17 Seed Broadcast, \"Evaluating the Fruits of Our Labor\", 8/23/17 What do you plan to do during the next reporting period to accomplish the goals?All field trialing and research activities described for Year 1 will continue in Year 2. In addition, seed increase of promising genetic stocks included in trials will be expanded. Future educational events planned for Year 2: Presentations on breeding for organic and the CIOA2 project will be delivered at selected regional vegetable growers meetings including the Pacific Northwest Vegetable Meeting, Kennewick, WA; Carolina Farm Stewards Association Conference; Seed Sovereignty Field Day/NOFA, Dartmouth, MA; Great Lakes Fruit, Vegetable, and Farm Market Expo, Grand Rapids, MI; Organic Seed Growers Conference, Corvallis, OR; Organicology Conference, Portland, OR; Organic Agriculture Research Symposium; Midwestern Organic and Sustainable Education Service (MOSES) Conference, LaCrosse, WI; ASHS, Washington DC; International Carrot Conference, Madison, WI; and International Apiaceae Meeting, Krakow, Poland. The project team holds an annual planning meetings in conjunction with the Organic Agriculture Research Symposium.

IMPACT

2019/09 TO 2020/08 What was accomplished under these goals? This project addresses the critical needs of organic carrot producers by developing orange and novel colored carrots with improved disease and nematode resistance, improved weed competitiveness, and improved nutritional value and flavor. About 100,000 acres of carrots are grown annually in the U.S. The 2014 Census of Agriculture, estimated 14% of this carrot production is in organic systems, vs. 3% for vegetable crops overall. Organic production of carrots has significant pest and disease challenges. Over 80% of the U.S. carrot production land is infested with one or more species of root-knot nematodes. Alternaria leaf blight (ALB), other foliar diseases and cavity spot are major carrot diseases in virtually all production areas of the world. The needs for effective non-chemical methods of pest and disease control to the future of the US organic vegetable production are urgent. Carrots are among the slowest crops for growers to establish, often making weed control the most expensive cost of organic production. Flavor and nutritional value are the most important characteristics noted by consumers of organic foods and novel colors attract carrot consumers. This project is developing novel carrots improved for nutrition and flavor, integrated with critical pest and disease resistance and vigorous growth. This project also expands our understanding of root-microbiome interactions critical for growth and nutrient uptake of organically-grown carrots. Goals and annual progress: Long-term goals of this project are to: 1) deliver carrot cultivars with improved disease and nematode resistance, improved nutrient acquisition, seedling vigor and weed competitive traits, increased marketable yield, superior nutritional value, flavor and other culinary qualities, and storage quality for organic production; 2) determine how carrot genotypes interact with/influence, the root microbiome to access key nutrients under limiting environments and avoid heavy metal uptake; 3) inform growers about cultivar performance to maximize organic carrot production, markets, and organic seed usage; 4) inform consumers about the positive environmental impact of organic production systems and about carrot nutritional quality, flavor and culinary attributes; and 5) train undergraduate, graduate, and post-doctorate students in critical organic agriculture issues. Primary activities: Focus Area 1: Cultivar development and release New breeding populations (\~45) were identified in the 2019-2020 winter root nursery. Three new orange breeding populations with improved flavor, carotene content, ALB and cavity spot resistance were advanced. The two purple breeding populations with improved flavor, texture, and robust agronomic production qualities were also advanced. Seven new breeding populations were started - one orange and six of novel colors, from roots produced in the winter root nursery. Successful production of seed to increase stock for widespread and larger scale trials of novel colored populations slated for release was accomplished. True-breeding selections of P1129 were advanced. Advanced selections were trialed by five organic seed companies and formal release is underway for three populations from CIOA1 (R6636, R6220, Y1246). Project partners are currently discussing release of the red carrot R6636 with one seed company. Focus Area 2: Variety trials on research stations and national participatory sites On-farm and on-station trials were radically impacted by covid-19, especially on-station trials at participating/collaborating Universities. Variety trials were held in WI, WA, and CA with participatory sites in OR, CO, VA, NY, ME, and VT. Included were 12 advanced breeding populations, check varieties, and selections from among 120 promising breeding populations. Flavor, marketability, productivity, pigment content and storage quality of selected CIOA entries was completed. Focus Area 3: Advancing research on root microbiome interactions A study to determine whether 4 carrot cultivars preferentially recruit AMF communities under organic management was carried out on five organic vegetable farms and the University of Wisconsin (UW) Research Station. Mean root colonization was significantly greater for one open pollinated variety which aligns with previous research where modern varieties of several crops demonstrate a loss of response to colonization by AMF to suggest that screening diverse genotypes may identify enhanced AMF colonization, to be used either directly be farmers or to be included in breeding programs.

AMF-associated soil proteins were not correlated to carrot cultivar at different farm sites but interesting interactions in the role of AMF in increasing soil proteins in more highly disturbed environments were suggested. This can be characteristic of organic farms with their reliance on tillage and cultivation indicating that it would be valuable to further investigate the role of cultivar selection and AMF inoculation on soil aggregation in heavily tilled/cultivated phases of the organic crop rotation, and in intensive vegetable production. Carrot taproots were found to be colonized by an abundant and diverse assortment of bacteria and fungi with greater diversity in organic management than conventional soils. Carrot genotype affected endophyte abundance in taproots and potential for individual isolates to affect seed germination, seedling growth and ALB tolerance was evaluated. Benefits of endophytes on carrot growth were greatest when plants were subjected to ALB stress, highlighting the importance of environmental conditions and the potential functional role of endophytes. This study demonstrates that endophytes can play an important role in improving carrot performance and mediating stress caused by ALB. Studies evaluating carrot root microbiome effects on nitrogen scavenging and heavy metal uptake are underway. Focus Area 4: Utilizing molecular markers to improve nematode resistance CIOA2 advanced experimental selections and promising selections were included in field trialing for resistance to prevalent root-knot nematodes occurring in California. Selected carrots were advanced for seed production to be included in genetic analysis, molecular marker evaluation, and breeding line development. Molecular marker evaluation this year found a major M. hapla resistance gene which is being fine-mapped to develop markers for breeders. Greenhouse tests were used to provide highly controlled screening conditions. Resistance traits for M. hapla, M. incognita and M. javanica were identified. Foliar diseases were diagnosed. Motley dwarf was identified for a third year in western WA trials, and also in central WA. ALB resistance was evaluated in central WI. Promising CIOA2 selections were identified where infection was high and wide variation in resistance was observed. Cavity spot resistance was tested for advanced CIOA2 breeding selections in infested fields in CA and WA and selections advanced for breeding. Focus Area 5: Evaluating and improving carrot flavor, nutritional, and postharvest quality CIOA varieties varied in appearance, texture, flavor intensity, acidity, sweetness and harshness. Overall flavor was rated on all samples and was positively correlated with sweetness but negatively correlated with harshness. Carrot flavor evaluation from the 2020 growing season is in progress. CIOA varieties slated for release were evaluated for flavor by chefs in 2019, but not in 2020 due to the COVID pandemic. Public educational events featured diverse advanced varieties at the first virtual OSA WA research farm field day and the Farm to Flavor event in Madison, WI (300+ attendees) in 2019. **PUBLICATIONS (not previously reported):** 2019/09 TO 2020/08 1. Type: Journal Articles Status: Published Year Published: 2020 Citation: Abdelrazek, S., Simon, P., Colley, M., Mengiste, T., Sulba, Jyothi *Hoagland, L., 2020. Changes in the core endophytic mycobiome of carrot taproots in response to crop management and genotype Scientific Reports doi.org/10.1038/s41598-020-70683-x 2. Type: Journal Articles Status: Published Year Published: 2020 Citation: Abdelrazek, S., Simon, P., Colley, M., Mengiste, T., *Hoagland, L., 2020. Crop management system and carrot genotype affect endophyte composition and Alternaria dauci suppression. PLOSOne doi.org/10.1371/journal.pone.0233783 3. Type: Theses/Dissertations Status: Submitted Year Published: 2020 Citation: Narda Silva.Characterizing carrot microbiomes and their potential role in soil organic matter decomposition. M.S. Thesis, Purdue University. 4. Type: Theses/Dissertations Status: Submitted Year Published: 2020 Citation: Leidy Meija. Carrot genotype and nitrogen stress alter plant soil feedbacks and susceptibly to pathogenic nematodes. B.S. thesis , Purdue University

2018/09 TO 2019/08 What was accomplished under these goals? This project addresses the critical needs of organic carrot producers by developing orange and novel colored carrots with improved disease and nematode resistance, improved weed competitiveness, and improved nutritional value and flavor. About 100,000 acres of carrots are grown annually in the U.S. The 2014 Census of Agriculture, estimated 14% of this carrot production is in organic systems, vs. 3% for vegetable crops overall. Organic production of carrots has significant pest and disease challenges. Over 80% of the U.S. carrot production land is infested with one or more species of root-knot nematodes. Alternaria leaf blight (ALB), other foliar diseases and cavity spot are major carrot diseases in virtually all production areas of the world. The needs for effective non-chemical methods of pest and disease control to the future of the US organic vegetable production are urgent. Carrots are among the slowest crops for growers to establish, often making weed control the most expensive cost of organic production. Flavor and nutritional value are the most important characteristics noted by consumers of organic foods and novel colors attract carrot consumers. This project is developing novel carrots improved for nutrition and flavor, integrated with critical pest and disease resistance and vigorous growth. This project also expands our understanding of root-microbiome interactions critical for growth and nutrient uptake of organically-grown carrots. Goals and annual progress: Long-term goals of this project are to: 1) deliver carrot cultivars with improved disease and nematode resistance, improved nutrient acquisition, seedling vigor and weed competitive traits, increased marketable yield, superior nutritional value, flavor and other culinary qualities, and storage quality for organic production; 2) determine how carrot genotypes interact with/influence, the root microbiome to access key nutrients under limiting environments and avoid heavy metal uptake; 3) inform growers about cultivar performance to maximize organic carrot

production, markets, and organic seed usage; 4) inform consumers about the positive environmental impact of organic production systems and about carrot nutritional quality, flavor and culinary attributes; and 5) train undergraduate, graduate, and post-doctorate students in critical organic agriculture issues. Primary activities: Focus Area 1: Cultivar development and release Detailed crop improvement plans for diverse breeding materials were developed and seed increases of promising selections were initiated for national trial evaluation. Approx. 85 new breeding populations were identified in our winter root nursery. Three new orange breeding populations with improved flavor, carotene content, ALB and cavity spot resistance were advanced. Two purple breeding populations with improved flavor, texture and color were also developed. A final round of selection and seed increase of three novel colored populations slated for release from CIOA1 (R6636, R6220 and Y1246) were selected in the 2019 winter nursery and grown to seed. Half-sib family selection to removed recessive orange roots from the purple P1129 population was exercised. Advanced selections were trialed by four organic seed companies and formal release is underway. Focus Area 2: Variety trials on research stations and national participatory sites Variety trials were held in IN, WI, WA, and CA with participatory sites in WA, VA, and VT. Included were 12 advanced breeding populations, check varieties, and selections from among 34 promising breeding populations. Flavor, carotenoid and anthocyanin content and storage quality of all CIOA entries was completed. Focus Area 3: Advancing research on root microbiome interactions In year 3, the relationship between carrot genotype and arbuscular mycorrhizal fungi associations under organic production conditions was evaluated, including four carrot cultivars (two heirlooms and two hybrids) of carrots and their propensities to benefit from inoculation with isolates of arbuscular mycorrhizal fungi in organic field conditions with and without late-season water restriction. Inoculants included geographically-distinct isolates from four species (Funneliformis mosseae, Rhizophagus clarus, R. intraradices, and Septoglomus deserticola). Carrot cultivars differed significantly in their response to inoculation, with heirloom cultivars demonstrating a higher propensity to benefit compared to hybrid cultivars. However, there was no consistent benefit or cost associated with inoculation, regardless of water conditions. Results were published and research expanded in 2019 to investigate interactions between carrot cultivar and the native soil microbiome on working organic farms, to determine if different carrot genetics respond differently to variation in soil biology. Data is being analyzed with evaluations continuing. Carrot taproots were found to be colonized by an abundant and diverse assortment of bacteria and fungi with greater diversity in organic management than conventional soils. Carrot genotype affected endophyte abundance in taproots and potential for individual isolates to affect seed germination, seedling growth and ALB tolerance was evaluated. Benefits of endophytes on carrot growth were greatest when plants were subjected to ALB stress, highlighting the importance of environmental conditions and the potential functional role of endophytes. This study demonstrates that endophytes can play an important role in improving carrot performance and mediating stress caused by ALB. Studies evaluating carrot root microbiome effects on nitrogen scavenging and heavy metal uptake are underway. Focus Area 4: Utilizing molecular markers to improve nematode resistance CIOA2 advanced experimental selections and promising selections were included in field trialing for resistance to prevalent root-knot nematodes occurring in California. Selected carrots were advanced for seed production to be included in genetic analysis, molecular marker evaluation, and breeding line development. Molecular marker evaluation this year narrowed genomic regions flanking the six major nematode resistance genes identified to date. Three new genomic regions contributing to resistance were discovered in 2018, and are being fine-mapped to develop markers for breeders. Continuation of greenhouse and field-screening for nematode resistance were carried out using sites in Parlier, CA. Greenhouse tests were used to provide highly controlled screening conditions. Resistance traits for M. hapla, M. incognita and M. javanica were identified. Foliar diseases were diagnosed when identity was uncertain. Motley dwarf was identified for a second year in Chimicum, WA trials. ALB resistance was evaluated in central Wisconsin. Promising CIOA2 selections were identified where infection was high and wide variation in resistance was observed. Cavity spot resistance was tested for advanced CIOA2 breeding selections in infested fields in CA and WA and selections advanced for breeding. Focus Area 5: Evaluating and improving carrot flavor, nutritional, and postharvest quality CIOA varieties were evaluated in November 2018, in separate groupings for different colors. Evaluation included appearance and texture, as well as flavor intensity, acidity, sweetness and harshness. Overall flavor was rated on all samples and was positively correlated with sweetness but negatively correlated with harshness. Carrot flavor evaluation from the 2019 growing season is in progress. CIOA varieties slated for release were evaluated for flavor by chefs evaluated for flavor. Public educational events also featured diverse advanced varieties, at the OSA WA research farm field day and the Farm to Flavor event in Madison, WI (300+ attendees) in 2019. Breeding lines from CIOA2 were shared with attendees at the and public taste test data was collected. **PUBLICATIONS (not previously reported):** 2018/09 TO 2019/08 1. Type: Journal Articles Status: Awaiting Publication Year Published: 2020 Citation: Keller-Pearson, M., Yang Liu, A. Peterson, K.Pederson, L. Willems, J.-M. Ané, E.M. Silva. 2020. Inoculation with arbuscular mycorrhizal fungi has a more significant positive impact on the growth of open-pollinated heirloom varieties of carrots than on hybrid cultivars under organic management conditions. Agriculture, Ecosystems & Environment 289: 15. 2. Type: Journal Articles Status: Submitted Year Published:

2020 Citation: Abdelrazek, S., Simon, P., Colley, M., Mengiste, T., Hoagland, L., (submitted). Crop management system and carrot genotype affect endophyte composition and Alternaria dauci suppression. PLOSOne

2017/09 TO 2018/08 What was accomplished under these goals? This project addresses the critical needs of organic carrot producers by developing orange and novel colored carrots with improved disease and nematode resistance, improved weed competitiveness, and improved nutritional value and flavor. About 100,000 acres of carrots are grown annually in the U.S. The 2014 Census of Agriculture, estimated 14% of this carrot production is in organic systems, vs. 3% for vegetable crops overall. Organic production of carrots presents several significant challenges from pests and diseases. Over 80% of the U.S. carrot production land is infested with one or more of the common species of root-knot nematodes. Alternaria leaf blight, other foliar diseases and cavity spot are major carrot diseases in virtually all production areas of the world. It is urgent and vital to the future of the US organic vegetable industry that effective non-chemical methods of nematode and leaf blight control be developed. Carrots are one of the slowest crops for growers to establish and grow. This often makes weed control the most expensive cost of organic carrot production. Flavor and nutritional value are the most important characteristics noted by consumers of organic foods. Among novel colored carrots are breeding stocks with some of the most vigorous growing seedlings and large tops. This project is developing novel carrots improved for nutrition and flavor, integrated with critical pest and disease resistance and vigorous growth. This project also expands our understanding of root-microbiome interactions critical for growth and nutrient uptake of organically-grown carrots. Goals and annual progress: The long-term goals of this project are to: 1) deliver carrot cultivars with improved disease and nematode resistance, improved nutrient acquisition, seedling vigor and weed competitive traits, increased marketable yield, superior nutritional value, flavor and other culinary qualities, and storage quality for organic production; 2) determine how carrot genotypes interact with, or influence, the root microbiome to access key nutrients under limiting environments and avoid heavy metal uptake; 3) inform growers about cultivar performance to maximize organic carrot production, markets, and organic seed usage; 4) inform consumers about the positive environmental impact of organic production systems and about carrot nutritional quality, flavor and culinary attributes; and 5) train undergraduate, graduate, and post-doctorate students in critical organic agriculture issues. Primary activities: Focus Area 1: Cultivar development and release We have developed detailed breeding plans for diverse breeding materials and have initiated seed increases of promising selections to be grown at all national trial sites. Selection of new breeding populations for CIOA2 in our winter root nursery identified \~85 new germplasm sources for evaluations. Seed was produced and included in the winter root nursery. Three new orange breeding populations have been created with a combination of flavor, enhanced carotene content, Alternaria and cavity spot resistance. Two purple breeding populations have also been created with a focus on excellent flavor,texture and color. A final round of selection and seed increase of two populations slated for release from CIOA1 (Purple-Orange 1129 and Red 6636) will be initiated this winter. Focus Area 2: Variety trials on research stations and national participatory sites Variety trials were held in Indiana, Wisconsin, Washington, and California and participatory sites in Washington, Hawaii, Maine, Virginia and Vermont. Included were 12 advanced breeding populations check varieties, plus selections from among an additional 34 potentially promising breeding populations that varied among trial sites. Roots from trial locations were sampled for nutritional pigment and flavor analysis. Focus Area 3: Advancing research on root microbiome interactions Arbuscular mycorrhizal fungi (AMF) beneficially interact with host plants by colonizing host roots, forming structures called arbuscules that facilitate the movement of water and nutrients, most notably phosphorus, in exchange for plant sugars. AMF can boost host performance during drought and other stresses. We evaluated organically grown carrot cultivars to compare the influence of different AMF species on carrot growth during varying water-limiting soil conditions. Carrot cultivars differed in their response to water limitation. Benefits to carrot growth differed according to cultivar-mycorrhizal species pairing. In addition to AMF, an abundant and diverse assortment of other microbial taxa that can help carrots acquire nitrogen and withstand biotic and abiotic stress also colonizes carrots. We identified these microbes within the seeds and taproots of a diverse set of carrot genotypes and demonstrated that they have potential to improve seedling establishment, help carrots acquire nitrogen and phosphorous, and withstand assault by Alternaria dauci, a key carrot pest. Microbial populations in carrot roots that are antagonistic to A. dauci, were greater in organic than conventional farming systems, demonstrating the value of greater soil health in organic systems. Carrot genotype also affected the composition of these microbes indicating that it may be possible to select for these beneficial plant-microbial relationships in breeding programs. Additional studies to determine whether carrot root microbiomes can enhance nitrogen scavenging and exclude heavy metal uptake are underway, along with evaluation of new processing and imaging tools to enhance recovery of carrot endophytes and improve phenotypic evaluation of carrot characteristics. Focus Area 4: Utilizing molecular markers to improve nematode resistance CIOA2 advanced experimental selections and additional potentially promising selections were included in field trialing for resistance to the most prevalent root-knot nematodes occurring in California. Selected carrots were advanced for seed production to be included in the genetic analysis, molecular marker evaluation, and breeding line development. Molecular marker evaluation underway has developed molecular markers for narrower genomic regions flanking

the six major nematode resistance genes identified to date. Three new genomic regions contributing to resistance were discovered in 2018, and are being fine-mapped to develop markers for breeders. Foliar diseases were diagnosed when identity was uncertain. Motley dwarf was identified for a second year in Chimicum, WA trials. Alternaria leaf blight resistance was evaluated and promising selections identified in CIOA2 selections in central Wisconsin, Infection was high and wide variation in resistance was observed. Cavity spot resistance was tested for advanced CIOA2 breeding selections in infested fields in California and selections advanced for breeding. Focus Area 5: Evaluating and improving carrot flavor, nutritional, and postharvest quality CIOA varieties were evaluated by chefs participating in vegetable flavor evaluations including two varieties slated for release. These varieties were also tasted by attendees at the international carrot conference in Madison, WI in August 2018. The attendees included representatives from most of the major carrot breeding, seed and production companies globally. Public educational events also featured these two varieties, at the Variety Showcase in NYC September 24th and the Farm to Flavor event in Madison, WI on September 26th. Taste evaluations by project personnel and participating chefs on orange, red and purple breeding lines as well as check varieties are anticipated in November, to provide quantitative and qualitative feedback on their culinary qualities. Evaluation of flavor, carotenoids and anthocyanins of all CIOA carrots is ongoing. Postharvest storage quality (rots, sprouting) is being noted. **PUBLICATIONS (not previously reported):** 2017/09 TO 2018/08 Type: Journal Articles Status: Published Year Published: 2018 Citation: Turner, S.D., P.L. Maurizio, W. Valdar, B.S. Yandell, and P.W. Simon. Dissecting the genetic architecture of shoot growth in carrot (Daucus carota L.) using a diallel mating design. G3 8:411-426. 2018.

2016/09 TO 2017/08 What was accomplished under these goals? This project addresses the critical needs of organic carrot producers by developing orange and novel colored carrots with improved disease and nematode resistance, improved weed competitiveness, and improved nutritional value and flavor. About 100,000 acres of carrots are grown annually in the U.S. The 2014 Census of Agriculture, estimated 14% of this carrot production is in organic systems, vs. 3% for vegetable crops overall. Organic production of carrots presents several significant challenges from pests and diseases. Over 80% of the U.S. carrot production land is infested with one or more of the common species of root-knot nematodes. Alternaria leaf blight, other foliar diseases and cavity spot are major carrot diseases in virtually all production areas of the world. It is urgent and vital to the future of the US organic vegetable industry that effective non-chemical methods of nematode and leaf blight control be developed. Carrots are one of the slowest crops for growers to establish and grow. This often makes weed control the most expensive cost of organic carrot production. Flavor and nutritional value are the most important characteristics noted by consumers of organic foods. Among novel colored carrots are breeding stocks with some of the most vigorous growing seedlings and large tops. This project is developing novel carrots improved for nutrition and flavor characteristics, integrated with critical pest and disease resistance traits, and vigorous growth. This project also expands our understanding of root-microbiome interactions critical for growth and nutrient uptake of organically-grown carrots. Goals and annual progress: The long-term goals of this project are to: 1) deliver carrot cultivars with improved disease and nematode resistance, improved nutrient acquisition, seedling vigor and weed competitive traits, increased marketable yield, superior nutritional value, flavor and other culinary qualities, and storage quality for organic production; 2) determine how carrot genotypes interact with, or influence, the root microbiome to access key nutrients under limiting environments and avoid heavy metal uptake; 3) inform growers about cultivar performance to maximize organic carrot production, markets, and organic seed usage; 4) inform consumers about the positive environmental impact of organic production systems and about carrot nutritional quality, flavor and culinary attributes; and 5) train undergraduate, graduate, and post-doctorate students in critical organic agriculture issues. Primary activities: Focus Area 1: Cultivar development and release We have developed detailed breeding plans for diverse breeding materials and have initiated seed increases of promising selections to be grown at all national trial sites. Preliminary selection of potential new breeding populations for CIOA2 in our winter root nursery identified \~85 new germplasm sources for inclusion in future evaluations. Seed was produced in our summer seed nursery and included in the 2017-18 winter root nursery. Three new orange breeding populations have been created - one with a focus on superior flavor, a second with a combination of flavor, enhanced carotene content, with Alternaria and cavity spot resistance, and a third with enhanced carotene content and flavor. A final round of selection and seed increase of two populations slated for release from CIOA1 (Purple-Orange 1129 and Red 6636) will be initiated this winter. Focus Area 2: Variety trials on research stations and national participatory sites Variety trials where held on four research stations across the nation by co-PIs in Indiana, Wisconsin, Washington, and California and 2 participatory sites in Virginia and Vermont. These trials included 12 advanced breeding populations and commercially available check varieties common to all sites plus selections from among an additional 34 potentially promising breeding populations that varied among trial sites. Roots of all breeding populations and checks from trial locations were sampled for nutritional pigment and flavor analysis. Trial results are being summarized and analyzed. Focus Area 3: Advancing research on root microbiome interactions Arbuscular mycorrhizal fungi (AMF) beneficially interact with host plants by colonizing host roots, forming structures called arbuscules that facilitate the movement of water and nutrients, most notably

phosphorus, in exchange for plant sugars. AMF can boost host performance during drought and other stresses. We evaluated organically grown carrot cultivars to compare the influence of different AMF species on carrot growth during varying water-limiting soil conditions. Carrot cultivars differed in their response to water limitation. Benefits to carrot growth differed according to cultivar-mycorrhizal species pairing. Uptake of sufficient nitrogen (N) during critical periods of plant growth is challenging in organic farming systems. At the same time, as production in urban and marginal areas increases worldwide, heavy metal uptake from contaminated soil has become an important food safety consideration. We observed differences in root architecture and microbial community structure among carrot genotypes. Genotypic differences in N and heavy metal uptake were also observed in carrot, but their relationship with various root characteristics has not yet been determined. Among a wide range of carrot germplasm evaluated, N and carbon partitioning among soil and root components was tracked using stable isotopes. Functional root characteristics are being identified using root imaging, analytical chemistry and microbial community profiling. Focus Area 4: Utilizing molecular markers to improve nematode resistance CIOA2 advanced experimental selections and additional potentially promising selections were included in field trialing in Irvine, California for resistance to the most prevalent root-knot nematodes occurring in California and other warm-season carrot production areas (Meloidogyne javanica and M. incognita). Selected carrots from these populations were advanced for seed production to be included in the genetic analysis, molecular marker evaluation, and breeding line development. Molecular marker evaluation underway has progressed to develop molecular markers for narrower genomic regions flanking the six major M. incognita resistance genes identified to date. GBS mapping has been completed and fine-mapping is underway. Foliar diseases were diagnosed when identity was uncertain. Alternaria leaf blight resistance (ALBR) was evaluated in CIOA2 advanced experimental selections and additional potentially promising selections in central Wisconsin, Infection was high and wide variation in resistance was observed. An investigation of the association between ALBR and phylogenetic relationships in diverse carrots revealed top height to be associated with resistance. Cavity spot (caused by Pythium sp.) resistance was tested for advanced CIOA2 breeding selections in infested fields in California and selections advanced for breeding. Focus Area 5: Evaluating and improving carrot flavor, nutritional, and postharvest quality Flavor evaluation of fresh carrot is underway and will be completed for carrots from all trials. Chefs who have been participating in vegetable flavor evaluations featuring different varieties that are showing promise for organic agriculture are expected to provide a more detailed flavor test of two varieties carrots developed through the CIOA1 project that are being trialed and released during CIOA2. Taste evaluations by seven chefs on orange, red and purple breeding lines as well as check varieties are anticipated to provide quantitative and qualitative feedback on their culinary qualities later this year. Samples were collected to evaluate carrot nutritional carotenoids and anthocyanins with HPLC for all entries of all field trials. Postharvest storage quality (rots, sprouting) is being noted for all of these samples. **PUBLICATIONS (not previously reported):** 2016/09 TO 2017/08 1. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Simon, P.W., Zystro, J, Roberts, P.A., Waters, T., Colquhoun, J., Navazio, J., Colley, M., McCluskey, C., Hoagland, L., duToit, L., Silva, E., Nunez, J. The CIOA (Carrot Improvement for Organic Agriculture) Project: Location, cropping system, and genetic background influence carrot performance including top height and flavor. Acta Hort.1153: 1-8. 2017. 2. Type: Journal Articles Status: Published Year Published: 2017 Citation: Arbizu, C.I., P.Tas, P.W. Simon, D.M. Spooner Phylogenetic prediction of carrot leaf blight resistance in wild and cultivated species of carrots. Crop Sci. 57:2645-2653. 2017.

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Lab to Farm: Integrating Organic Cucurbit Science and Production in the Midwest

Accession No.	1010373
Project No.	MICL05097
Agency	NIFA MICL\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2016-51300-25732
Proposal No.	2016-04458
Start Date	01 SEP 2016
Term Date	31 AUG 2019
Grant Amount	$999,917
Grant Year	2016
Investigator(s)	Szendrei, Z.

NON-TECHNICAL SUMMARY

We propose to develop a stakeholder-driven, integrated regional project for organic cucurbit management in the Midwest. Our long-term goal is to partner with growers to develop management tools that provide an economic advantage while mitigating environmental costs. Cucurbits are one of the top five organically produced vegetable crops, and diseases, insect pests and nutrient management are the most important management issues for growers. Our team includes three Midwestern states, a multidisciplinary research and extension team, and an advisory panel of organic growers. We identified stakeholder needs through a 2016 online organic cucurbit grower survey and created a grower advisory panel for the duration of the grant. The top priorities for growers are; improved weed management tools, development of reduced tillage practices, integration of cover crops into fertility and weed management practices, improvement of nitrogen management methods, identification of effective cucumber beetle management tools, and improvement of downy mildew and Phytophthora management. In addition, farmers were interested in understanding the role of native bees as cucurbit pollinators. To address these grower priorities, our scope of work involves seven objectives that include a greenhouse trial, several research-farm plot trials, on-farm trials, testing of new management methods by growers in their farms and delivery of outcomes to our traget audience. Our project contibutes to four of the 2016 OREI priority areas and will deliver seven novel aspects, including the testing of seggregated and living cover crops for nutrient and pest management, and the evaluation of recently developed resistant cucurbit varities in our region.

OBJECTIVES

We will develop a stakeholder-driven, integrated systems project for organic cucurbit production in the Midwest that tackles multiple management problems. Our long-term goal is to partner with growers to develop and define management tools that provide an economic advantage while mitigating environmental costs. Cucurbits are one of the top five organically produced vegetable crops, and diseases, insect pests and nutrient management are the most important issues for organic grower.Our team includes three Midwestern states (MI, IN, WI), a multidisciplinary research and extension team, and an advisory panel of organic growers. This team positions us well to address priority grower concerns specific to our region. We will conduct four research and three outreach/extension objectives as a part of this integrated project related to nutrient, weed, insect, and disease management in organic cucurbits.Our objective is toinvestigate 1) the impact of strip tillage and cover crops on pests, beneficials and nutrients; 2) nutrient management strategies for plasticulture-grown cucurbits; 3) cucurbit

beetle management using perimeter trap crops; 4) cultural and mechanical tools for weed management; and 5) use citizen science to survey bees in cucurbits; 6) implement organic cucurbit production systems on growers\' farms; 7) develop extension materials for our target audience.

APPROACH

Thisproject is designed to provide continuous engagement between organic growers and co-investigators to improve cucurbit management in the Great Lakes region. The researchers will interact with an organic grower advisory panel throughout the project period, remaining open to changes in experiments based on the panel\'s feedback. The purpose of the grower advisory panel is also to provide immediate, on-farm tests of our project\'s newly developed tools. This will provide a seamless link between experimentation and application (\'lab to farm\'). On-farm demonstration trials will highlight constraints and adjustments required to optimize management systems, elucidate the effects of management methods on weeds, nutrients, diseases and insects, and aid organic producers with the adoption of new methods appropriate for their farm. On-farm demonstration trials will also provide venues for field days where growers can exchange experiences.The scopeofwork involves a greenhouse trial, research-farm plot trials, on-farm trials and testing of new management methods by growers in their farms. Replicated trials will facilitate detailed assessment of cucurbit management methods, and on-farm systems experiments will highlight compatibility of new methods with existing ones. The majority of the experiments outlined in the project are testing management systems instead of unique management methods in isolation. Our multidisciplinary team is uniquely positioned to tackle multiple aspects of management systems in combination (weeds, diseases, insects, nutrients). Our results will be disseminated to growers at multiple venues, through a diversity of platforms.We will build curriculum for the Michigan State University Student Organic Farm\'s education programs for new and experienced organic farmers. Our online outreach will include posting webinars and educational videos developed during this project. In addition, we will incorporate a unique outreach component using citizen science for a bee survey. **Progress** 09/01/16 to 08/31/21 -- Final Report **Outputs** Target Audience: Nothing Reported Changes/Problems:The COVID-19 pandemic impacted Dr. Silva'sability to do field work on farm fields as well as field-based outreach events in both 2020 and 2021. All project participants took advantage of virtual events as much as possible to ensure outreach deliverables during this time. What opportunities for training and professional development has the project provided?In Brainard, Szendrei, Kaplan, Hayden,lab group, one MS student each had an opportunity get training and complete graduate research. In addition, 10 undergraduate research aides were trained through the various activities of this grant, including participation in field data collection and analysis for research farm experiments. How have the results been disseminated to communities of interest?Yes, we have conducted several field days, extension presentations and published news articles in grower oriented trade magazines as well as videos. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? Objective 1. In Michigan, we conducted a field trial in an organic squash field over three years, with four treatments consisting of several combinations of tillage and cover crop/mulch types. The abundance of herbivorous arthropods on foliage varied by taxa. Some species such as Anasa tristis had higher abundance in strip-tillage treatments relative to full-tillage, while a 21-47% reduction in the abundance of Aphididae was observed in strip-tilled and strip-tilled plots with additional mulch. Parasitoid wasps and epigeal natural enemies were more abundant in strip-tillage treatments. Conversely, a significant increase in Formicidae abundance was observed in full-tillage, coinciding with areas of highest Aphididae and lowest parasitoid wasp abundances suggesting that aphid-tending by Formicidae may have deterred and/or inhibited parasitoid wasps from attacking aphids. Strip-tillage did not increase flower visitation byE. pruinosa,a bee species that specializes on cultivated Cucurbita. Cover crop spatial segregation effects on arthropods were negligible. Supplemental mulch did not impact arthropods, except lower Aphididae and increased Parasitica abundances, and provided insufficient biomass to effectively suppress weeds in 2 of 3 years. Although strip-tillage reduced N availability and increased weed abundance relative to full-tillage, crop growth and yield were comparable in 8 of 9 cases. The cover crop field trial was evaluated for occurrence of disease symptoms including wilting, blighting, and root rot. All cover crops in the trial were free of disease symptoms. Significant differences in powdery mildew disease severity on the winter squash foliage among the different cover crop systems were not observed. In Wisconsin different between-row (aisle) and in-row mulches were compared to identify reduced tillage combinations that effectively manage weeds while minimizing yield. Aisle treatments included roller-crimped cereal rye mulch (RA), hay mulch (HA) and cultivated bare ground (CA), and in-row treatments included plastic mulch (PR), hay mulch (HR), and cultivated ground (CR). Plots managed with RA and HA had significantly less weed pressure as compared to CA treatments, although RA required more weed management time than HA, and weed suppression in RA was not as great at the end of the season. In addition, RA tended to result in slightly lower marketable yields, although not significant. However, when assessed as per plant yield to account for plant survival rates, RA yielded significantly less than cultivated aisles in 2018, with rot the most common cause of unmarketability. There as only a significant row mulch aisle mulch interaction during the 2019 season, and yield in plots with crimped rye

mulch in the aisle were not significantly affected by the type of in-row mulch. Pressure from squash bugs was also higher in high residue treatments (HA, RA, HR, PR). Twelve cover crop varieties were grown in a greenhouse and inoculated withP. capsici. Disease symptoms observed on inoculated plants included stunting, wilting, chlorosis, and plant death. Field peas, oilseed radish, and mustard developed disease symptoms significantly different than zero and field peas showed the greatest disease severity and yield reduction. Disease severity was only significant for hairy vetch and buckwheat and fresh weight yield was only significant for hairy vetch. Objective 2. We evaluated the effects of organic N fertilizer rate (low vs. high), timing (preplant vs. split applications), and plastic mulch use (black plastic mulch vs. bare ground) on slicing cucumber production, as well as evaluating the performance of a new downy mildew-resistant cucumber variety (DMR-401). DMR-401 yielded less than our standard variety (Cobra) during a year with no downy mildew disease pressure (2017), but performed significantly better than the standard variety. While plastic mulch maintained higher soil N availability compared to bare ground, cucumber yields were not higher on plastic. Plastic mulch increased total yields relative to bare ground in 2018, and lower N rates were required to maximize cucumber yields grown on plastic than on bare ground. Split applications of an organic N fertilizer through the drip system did not benefit cucumber yields or soil N availability in either year of the study. Between-row management strategies evaluated in plasticulture vegetable systems included cultivation, rye residue dead mulch, mowed weeds, and three living mulch species: rye monoculture, Italian ryegrass monoculture, and a rye-Dutch white clover mixture. Cultivation and dead mulch provided greater in-season weed control and reduced weed seedbank contributions relative to living mulches. Despite physical separation, plants growing between plastic mulch beds showed the potential to compete for in-row resources. However, yellow summer squash yields were unaffected by treatment in both years, while yields of bell pepper were reduced only in a relatively dry year. Plants growing between plastic mulch beds reduced inorganic nitrogen leaching. In a separate cover crop screen to evaluate species suitable as living mulches in plasticulture production, a significant negative correlation between weed and living mulch biomass was observed, with teff producing the most biomass and suppressing in-season weeds more than any other species. Objective 3. We investigated the potential of mass-trapping striped cucumber (SCB). We baited yellow gallon jug traps containing soapy water with a commercially available floral lure containing equal parts 1,2,4-trimethoxybenzene, indole, and trans-cinnamaldehyde and/or ten live SCB (serving to replicate aggregation pheromone). Overall, we captured nearly 7,000 beetles with most occurring in late May to early June. During two activity periods, we found seasonal variation in SCB behavioral response to the lures; namely, floral volatiles reduced numbers of captured beetles from the overwintering generation by 49% but increased their numbers from the second generation by 727%. There was a positive relationship between SCB trap capture and on-plant beetle counts within the sampled fields, but this depended on sampling date used in the analysis. Our results suggest that the same volatile stimulus can act as both a repellant and an attractant, depending on seasonality in multivoltine insects. Objective 4. Field and greenhouse studies were conducted to evaluate the potential for improving weed management in acorn squash through integration of cultural and physical approaches. Field experiments were carried out to test whether commercially availableCucurbita pepovarieties differed in their tolerance to mechanical disturbance from flextine cultivators and finger weeders, and to identify traits associated with that tolerance. For each tool, separate experiments were conducted in a split plot design, with weeding strategy (hand weeding vs flextine or finger weeding) as the main plot factor, andC. pepovariety (Taybelle, Jester, Delicata, Honey Bear, Sugarbush and Tuffy) as the subplot factor. In separate greenhouse studies, seedling traits including root:shoot ratio (RSR), projected area, and anchorage force were evaluated. Varietal differences in tolerance to both flextine cultivation and finger weeding were evident, results were variable and inconsistent. Tolerance to flextine cultivation under field conditions was positively correlated with plant size at the time of cultivation and to plant anchorage forces determined in the greenhouse. However, tolerance to finger weeding was not well correlated with seedling traits. Objective 5. Squash bees are sensitive to farm management practices, particularly those that disturb the soil. Survey results indicated that squash bees occupy a wide geographic range and are more abundant in farms with reduced soil disturbance. **Publications** - Type: Theses/Dissertations Status: Published Year Published: 2019 Citation: Benzle, M.M., 2019. Integrated Cultural and Mechanical Weed Management for Organic Winter Squash Systems (MS Thesis, Michigan State University). - Type: Journal Articles Status: Published Year Published: 2020 Citation: Tarrant, A.R., D.C. Brainard, and Z.D. Hayden. 2020. Cover crop performance between plastic-mulched beds: Impacts on weeds and soil resources. HortScience 55: 10691077. doi: 10.21273/HORTSCI14956-20. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Tarrant, A.R., and Z.D. Hayden. 2020. Cover crops between plastic mulch get mixed results. Vegetable Growers News. May 2020. p13. - Type: Journal Articles Status: Under Review Year Published: 2021 Citation: Shee C, Szendrei Z, Zhu H, Kaplan I. Opposing effects of floral lures on the behavior of overwintering and late-season generations of the striped cucumber beetle, Acalymma vittatum. Submitted to Environmental Entomology in September 2021; - Type: Journal Articles Status: Published Year Published: 2021 Citation: Parada-Rojas, C.H., Granke, L.L., Naegele, R.P, Hansen, Z., Hausbeck, M.K., et al. 2021. A Diagnostic Guide for Phytophthora capsici Infecting Vegetable Crops. Plant Health Progress (first look). Published online at https://doi.org/10.1094/PHP-02-21-0027-FI - Type: Conference Papers and Presentations Status: Published Year

Published: 2020 Citation: Hausbeck, M.K. 2020. Management of Phytophthora Blight in Processing Squash. Great Lakes Farm, Fruit and Vegetable Expo: Processing Vegetables 2. Virtual, 10 Dec. 167 attendees. - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Hausbeck, M.K. and Higgins, D.S. 2020. The Grounder, the Line Drive, and the Pop Fly: Fielding Three Very Different Vine Crop Diseases. Great Lakes Farm, Fruit and Vegetable Expo: Vine Crops 1. Virtual, 9 Dec. 178 attendees. - Type: Journal Articles Status: Under Review Year Published: 2021 Citation: Living mulch plasticulture systems for organic zucchini (Cucurbita pepo L.) production. Dylan Bruce, Erin Silva - Type: Journal Articles Status: Under Review Year Published: 2021 Citation: In-row management strategies for cover-crop based reduced tillage organic squash production impact marketable yield and weeding labor time. Dylan Bruce, Erin Silva - Type: Other Status: Published Year Published: 2021 Citation: Bruce, D. 2021. Reduced tillage vegetable production Week 2: Cover Crop-Based Reduced-Tillage Practices in Wisconsin with Dylan Bruce. Video - https://practicalfarmers.org/2021/08/rtvp-week-2-cover-crop-based-reduced-tillage-practices-in-wisconsin-with-dylan-bruce/

PROGRESS

2019/09 TO 2020/08 Target Audience: Nothing Reported Changes/Problems:Due to COVID19, we have not been able to travel to deliver our findings to growers and present in front of scientific audiences. We are also limited in our activites during Summer 2020, therefore we are requesting a 1 year no-cost extension. What opportunities for training and professional development has the project provided?Graduate students and undergraduate students have been trained in agriculture and scientific research over the reporting period. How have the results been disseminated to communities of interest?Over the course of the past year, we gave 15 extension presentations at grower meetings, conferences and field days and published 2 extension publications. What do you plan to do during the next reporting period to accomplish the goals?We are conducting some field experiments analyzing and publishing results, preparing progress reports and extension publications. We will also produce extension materials and presentations.

2017/09 TO 2018/08 Target Audience: Nothing Reported Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?We trained 6 graduate students in the areas of plant pathology, organic vegetable management, entomology and horticulture. We also trained master gardeners through webinars and face to face meetings to teach them about pollinator identification in squash. We also trained 7 undergraduate students in several aspects for sustainable squash management, and more broadly agriculture/research/extensions. How have the results been disseminated to communities of interest?We held a meeting for all the grant participants where we updated each other about our progress and future plans. We are in the final stages of developing a video about squash bees and squash pollination. We are actively sending out project updates through Twitter, and developed a website for the squash bee citizen science survey (http://vegetable.ent.msu.edu/squash-bee-project/). In September 2018, we had a field day in Michigan that was attended by \~40 people that reported the outcomes of the entire project. We are currently working on developing factsheets. We presented our outcomes at several meetings, such as the MI Master Gardener annual meeting in Spring 2018. We also developed two YouTube videos from a workshop that was held at the Annual Organic Alliance Meeting in 2017, these videos have been edited and posted online. We also presented our findings at the Annual Entomological Society meeting in November 2017. What do you plan to do during the next reporting period to accomplish the goals?We will continue to collect data from our field trials repeating the experiments that were done in 2018. We will continue to do extension, and outreach. In the last year of our project we will do data anaysis and publish our results.

2016/09 TO 2017/08 Target Audience:Our target audience is comprised of organic cucrbit growers in the Midwest. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?We have three graduate students hired on this project and one postdoc, we also had four undergraduate students working on this project during the field season. How have the results been disseminated to communities of interest?Yes, we held a workshop for organic growers in Spring 2017 to educate them about organic weed, insect and disease management. What do you plan to do during the next reporting period to accomplish the goals?We will continue to set up experiments and will hold a webinar for organic growers during winter 2017/2018.

IMPACT

2019/09 TO 2020/08 What was accomplished under these goals? Data is currently being analyzed for much of the collected data this winter and next spring and publications will be prepared as this progresses. Objective 1. We collected data for this experiment in MI and WI, the field was set up at experimental stations, we recorded number of insects on plants, disease symptoms and weeds in plots. Data for 2019 are still being analyzed, but preliminary results suggest that neither tillage (trt 1 vs 2), spatial arrangement (trt 2 vs 3) had any detectable effect on insects, disease, yield or quality of acorn squash (\'Taybelle\'). Supplemental mulch (trt 3 vs 4) also did not impact crop yield, but improved weed suppression and reduced weed management costs. Drone images from mid-season suggest that total leaf area and leaf greenness was greatest in the conventionally tilled treatments, perhaps due to greater early N availability. However, these differences appeared to dissipate with time, and did not result in detectable differences in crop yield. In WI, the first pest and disease data collection was conducted on July 16th, and was conducted weekly until August 27th. Weeding data was collected five times (7/3, 7/12, 7/23, 8/7, and 8/28/19). All treatments were harvested on September 3rd. Objective 2. In MI, late season plantings of DMR-401 yielded less than our standard variety (Cobra), but had significantly higher yields and extended production in a year with more typical disease pressure (2018). This trial finished in 2018, and publications are currently being prepared. In WI, Rye cover crop was planted in late September 2018. The cover crop was terminated the following spring on May 21st. Plastic for data and guard rows was laid on May 22nd, and the living mulch treatments were seeded by hand and raked in on May 23rd. Control treatments included bare soil and straw mulch and three living mulch treatments. The first pest, weed, and disease data collection occurred on July 9th and was conducted weekly thereafter until August 20th. Soil tests were conducted as outlined in the proposal, with soil cores obtained monthly. The first harvest was conducted on July 9th and happened as needed/able until August 15th, with a total of 15 harvests. The trial was terminated after August 20th because of a virus moving through the plots. Objective 3. During the summer of 2019 we replicated our experiment from last year, where we tested the effects of floral volatiles and live striped cucumber beetles (SCB) for mass trap-and-kill of SCB. Thirty-six traps were placed in zucchini plots at two locations in northwest Indiana\--a commercial organic farm and the Purdue University specialty crops farm. Traps were placed in late May, near SCB emergence, and were removed in early September when SCB activity began to decline. Each week, SCBs were scouted on 15 random plants within each plot to estimate the population. Trap contents were collected weekly and counted. In late May and early June, the control and beetle traps were most attractive to beetles and those containing floral lures, regardless of the presence or absence of beetles, was repellent. Few beetles were caught through the middle part of the summer and there were no differences in preference between treatments. However, that changed in late July when traps containing floral lures or beetles and floral lures became more attractive than traps containing beetles or nothing. Objective 4. In 2019, results were analyzed from 2 years of field trials evaluating the tolerance of 6 cultivars of acorn squash to finger weeding and flextine cultivation (Benzle MS thesis). Field studies demonstrated significant differences in cultivar tolerance to both the finger weeder and flextine cultivator in at least one repetition of each experiment. Objective 5. We conducted 4 workshops to educate Master Gardener Citizen Scientists over the past year and we received 101 electronic and 42 print survey submissions. We are currently working on a publiaction to summarize our findings for the three project years. This publication will be a thesis chapter for an MS graduate student. Objective 6. Over the course of the past year, we gave 15 extension presentations at grower meetings, conferences and field days and published 2 extension publications. We conducted cucurbit grower focus groups in Indiana and Wisconsin. Attempts to conduct a Michigan focus failed due to inability to gain commitment from enough growers on the same date. We are in the process of analyzing this dataset. Objective 7. We are presenting the information at extension and research conferences and meetings and preparing furhter extension materials. **PUBLICATIONS (not previously reported):** 2019/09 TO 2020/08 1. Type: Theses/Dissertations Status: Submitted Year Published: 2020 Citation: INVESTIGATING THE IMPACTS OF GROUND MANAGEMENT ON ARTHROPODS IN ORGANIC CUCURBITA AGROECOSYSTEMS By Logan R. Appenfeller, MSU Thesis, ProQuest 2. Type: Journal Articles Status: Published Year Published: 2020 Citation: Appenfeller, L., Lloyd, S., Szendrei, Z. (2020) Citizen science improves our understanding of soil management on wild pollinator abundance in agroecosystems. PLoS ONE 15(3): e0230007. https://doi.org/10.1371/journal.pone.0230007

2017/09 TO 2018/08 What was accomplished under these goals? OBJ1. The impact of strip tillage and cover crops on pests, beneficials and nutrients. In Michigan, we completed the second year of a three-year field trial evaluating the impact of tillage (strip tillage vs conventional full width tillage) and cover crop spatial arrangement (full width mixture vs segregated plantings) planting on weeds, insects, disease and crop yield and quality. Four experimental treatments were evaluated: 1) Conventional tillage + standard rye-vetch mixture; 2) Strip tillage + standard rye-vetch mixture; 3) Strip tillage + rye/vetch segregated planting; and 4) Strip tillage + rye segregated planting + supplemental rye residue between crop rows. Experimental plots were established as a randomized complete block design with four treatments and six replications at the Kellogg Biological Station. In August, rye and vetch cover crop mixtures were planted either as a full width mixture (trts 1&2), or in segregated strips (trts 3&4), with the vetch component sown in the zone where the crop was planted the next spring, and rye sown in

the between row zone. A cucumber trial evaluating the effects of different nitrogen management practices was also evaluated for downy mildew disease severity. The level and timing of nitrogen applications (Low Preplant, High Preplant, High Split) and the use of plastic mulch were not significant factors in the percentage of the plant foliage with downy mildew lesions. However, the two varieties were significantly different with respect to their susceptibility to downy mildew. Cobra and DM-401 averaged 87.8% and 20.0% respectively, for the percentage of the plant foliage with downy mildew lesions. OBJ3. Cucumber beetle management using perimeter trap crops. We found that SCBs are phototactic and that the best way to get a response in the y-tube was to perform trials under red light with a slight elevation of the y-tube. A choice was recorded once each beetle passed into the cap at the end of the terminal and no choice was recorded if the beetle did not reach this point within three minutes. Trials contained: TIC vs. air, male-damaged plants vs. undamaged plants, female-damaged plants vs. undamaged plants, male-damaged plants vs. female-damaged plants, floral volatiles (1,2,4-trimethoxybenzene, indole, trans-cinnamaldehyde, aka \"TIC\") vs. floral + foliar volatiles (TIC + trans-2-hexan-1-ol) and bacterial wilt (Erwinia tracheiphila) infected vs. uninfected plants. We found that plants that had been fed on for two days by male SCBs were more attractive to male SCB than those that had been fed on for two days by two female SCBs. We also found that plants infected with bacteria wilt tended to be more attractive to SCB, although the sample size was too small to reach significance. This summer we studied the effects of floral volatiles and live SCB for mass trapping with gallon jugs. Our lures were purchased from TRÉCÉ, Inc. and contained the floral volatiles 1,2,4-trimethoxybenzene, indole, trans-cinnamaldehyde (TIC).SCBs were collected from the wild for use as live bait and were maintained in the laboratory until needed. After use, the wild-caught SCB were brought back to the laboratory and added to our SCB colony to increase genetic diversity. The traps were placed in late-May when SCB began to emerge and were removed in mid-September when SCB activity began to cease. Each week, SCBs were counted on 15 randomly chosen plants within each plot to estimate the SCB population. Trap contents were collected each week to count captured SCB and preserved to later identify sex. We presented our research at the open house for the Master Gardener\'s Association of Tippecanoe County in July. We will also present the results from this summer at the Entomological Society of America in Vancouver, Canada this November. The title of the presentation is: Come together (over me): Aggregation pheromones and floral volatiles in striped cucumber beetle mass trapping. OBJ4. Integrate cultural and mechanical tools for weed management. In 2018, 6 cultivars of C. pepo were evaluated in three separate field experiments conducted at the KBS research station to test: 1) tolerance of these cultivars and weeds to finger weeding; 2) tolerance to flextine cultivation; and 3) emergence and early growth under different levels of tillage (strip till vs no till) and cover cropping. Each of the two cultivation tolerance trials (1 and 2) was repeated. Crop survival, physiological responses to stress, and early growth (biomass at 30-40 DAS) were evaluated in all trials. Characteristics evaluated included seed size, time to emergence, seed vigor, early seedling growth and partitioning, root morphology and anchorage force (force required to uproot seedlings). Cultivars also varied substantially in their emergence and early growth characteristics. For example, the cultivar \"Taybelle\" typically emerged 1-2 days earlier than several other cultivars, and was taller at the optimal time for mechanical cultivation. Variation in cultivar tolerance to reduced tillage is currently being analyzed. Preliminary analysis demonstrates that all cultivars had reduced growth early growth under no-till compared to tilled soil conditions; however, it is still unclear whether practical differences in tolerance to no-till exist between the 6 cultivars evaluated. OBJ5. Conduct squash bee survey using citizen science. A webinar was held on 6/27/18 that allowed new and previous participants of the citizen science squash bee survey to view an online presentation and ask questions regarding background information on the project and some results from the 2017 squash bee survey data. This webinar was attended by about 100 citizen scientists. Squash bee pollinator citizen science workshops were held on 7/16/18 (Mason, MI), 7/20/18 (Novi, MI), 7/25/18 (Grand Rapids, MI), and 7/27/18 (Lincoln, MI via Zoom). Attendees were told about the citizen science squash bee survey and how they could download and operate the associated smart phone app and participate. Instructions were also provided on how to access the web browser and PDF versions of the survey. OBJ6. Implement organic cucurbit production systems on growers\' farms. We are currently working with several growers collaborators who are now testing mechanical weeding equipment in their organic cucurbit production. We are also conducting on-farm trials with nutrient and cover crop management and will interview growers to evaluate their practical benefits and problems. OBJ7. Develop extension materials from the project and deliver outcomes to our target audience. We held a meeting for all the grant pariticpants where we updated each other about our progress and future plans. We are in the final stages of developing a video about squash bees and squash pollination. We are actively sending out project updates through Twitter, and developed a website for the squash bee citizen science survey. In September 2018, we had a field day in Michigan that was attended by \~40 people that reported the outcomes of the entire project. We are currently working on developing factsheets. We presented our outcomes at several meetings, such as the MI Master Gardener annual meeting in Spring 2018. We also developed two YouTube videos from a workshop that was held at the Annual Organic Alliance Meeting in 2017, these videos have been edited and posted online. We also presented our findings at the Annual Entomological Society meeting in November 2017. We also completed a baseline survey of organic cucurbit growers in Indiana, Michigan, and Wisconsin. We conducted a feedback survey and observation data collection

at a Michigan field day. We are currently finalizing comprehensive reports for survey results and organizing farmer focus groups in each state **PUBLICATIONS (not previously reported):** 2017/09 TO 2018/08 1. Type: Websites Status: Published Year Published: 2017 Citation: http://vegetable.ent.msu.edu/squash-bee-project/ 2. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Hayden, Z.D. and A. Tarrant. 2018. Innovative cover cropping strategies for vegetables. Southwest Michigan Horticultural Days. February 7. Benton Harbor, MI. (Oral) 3. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Hayden, Z.D. and A. Tarrant. 2018. Organic N fertility management and cover crop research update. MSUE Vegetable Tour. August 13. Benton Harbor, MI. (Oral) 4. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Hayden, Z.D. 2018. Fertility management in organic systems. Organic Management Field Day. Kellogg Biological Station. September 19. Hickory Corners, MI. (Oral) https://events.anr.msu.edu/event.cfm?eventID=D3989960411F3A3F (accessed 30 September 2018). 5. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Hayden, Z.D. 2018. Organic nutrient management. MSU Student Organic Farm Farmer Field School. Crop Fertility Workshop. October 7. Holt, MI. (Oral) 6. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Hayden, Z.D. and A. Tarrant. 2017. Cover crop and N fertility management for organic plasticulture production. SWMREC Station Research Field Tour. August 15. Benton Harbor, MI. (Oral) 7. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Hayden, Z.D. and A. Tarrant. 2017. SWMREC organic field research update. MSUE Vegetable Tour. August 28. Benton Harbor, MI. (Oral) 8. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Tarrant, A., Z.D. Hayden, and D.C. Brainard. 2017. Optimizing between-row management strategies in plasticulture vegetables for improved crop production and soil health. Great Lakes Expo. Grand Rapids, MI. December 5-December 7. (Poster) 9. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Tarrant, A., Z.D. Hayden, and D.C. Brainard. 2018. Optimizing between-row management strategies in plasticulture vegetables for improved crop production and soil health. Great Lakes Vegetable Working Group Annual Meeting. Grand Rapids, MI. February 27-February 28. (Oral) 10. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Tarrant, A and, Z.D. Hayden. 2018. Optimizing between-bed management strategies in plasticulture vegetables. Sustainable Agriculture Research and Education Our Farms, Our Future Conference. St. Louis, MO. April 3-April 5. (Poster) 11. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Tarrant, A and, Z.D. Hayden. 2018. Optimizing between-bed management strategies in plasticulture vegetables. Midwest Ecology and Evolution Conference. Hickory Corners, MI. April 6-April 8. (Poster) 12. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Galley, S., Szendrei, Z. The impact of strip tillage and cover crops on pests and beneficials in organic squash. Annual Meeting of the Entomological Society of America, Nov. 5-8, 2017, Denver, CO. Student Poster Competition. 13. Type: Journal Articles Status: Published Year Published: 2018 Citation: Field day features organic farming challenges and solutions. MSUE Vegetable News. Sep. 4, 2018. 14. Type: Journal Articles Status: Published Year Published: 2018 Citation: Interested in learning about pollinators? Participate in a squash bee survey! MSUE Vegetable News. July 20, 2018. 15. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Tarrant, A., Z.D. Hayden, D.C. Brainard, and L.K. Tiemann. 2018. Optimizing between-row management strategies in plasticulture vegetables for improved crop production and soil health. Plant Science Graduate Student Research Symposium. East Lansing, MI. March 30. (Oral) 16. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Tarrant, A., Z.D. Hayden, D.C. Brainard, and L.K. Tiemann. 2018. Optimizing between-row management strategies in plasticulture vegetables for improved crop production and soil health. Plant Science Graduate Student Research Symposium. East Lansing, MI. March 30. (Poster) 17. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Tarrant, A. and Z.D. Hayden. 2018. Covering ground: A systems evaluation of between-row management strategies in organic plasticulture vegetable production. American Society for Horticultural Science Annual Conference. Washington, DC. July 31-August 3. (Oral) 18. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Szendrei, Z., Hausbeck, M. What?s killing my vegetables? Workshop at the Midwestern Organic Farming Conference. La Crosse, WI. Feb. 22-24, 2018. 19. Type: Other Status: Published Year Published: 2017 Citation: Squash bee app for citizen scientists

2016/09 TO 2017/08 What was accomplished under these goals? Obj 1. The impact of strip tillage and cover crops on pests, beneficials and nutrients. Randomized complete block design experiment was set up at a research stations in MI. The 4 treatments consisted of a combination of cover crop placement (mixed or banded) and tillage (strip, chisel). Winter squash was sampled for insects, diseases and weeds throughout the 2017 growing season - data collection and analysis are still ongoing. In Michigan, no differences were observed among treatments for foliar diseases, but mulched plots had significantly higher activity density of natural enemies than plots without mulch and this trend was positively correlated with the amount of mulch. Twelve cover crop varieties were tested in the greenhouse for their susceptibility to Phytophthora capsici. Field peas, oilseed radish, and

mustard developed disease symptoms that differed from zero, but disease severity varied. Most field peas were dead by the end of the trial while oilseed radish and mustard had minor stunting and some chlorosis. P. capsici caused 20% yield reduction in hairy vetch, but no visual symptoms were detected. Experimental plots were established as a randomized complete block design with four treatments and six replications at university research farm in Verona, WI. Each plot was 10 x 10 m in size. In September, in plots with segregated cover crop treatments, cereal rye was seeded between rows at a planting rate of 3 bu/acre. At that same time, red clover (WI) will be seeded at a rate of 15 lbs/acre respectively, in bands where the crop will be planted next spring. The cover crops continued to develop until next May, when a roller-crimper terminated the cereal rye. cover crop residue into the soil in the crop rows but leave mulch between the rows. Cover crop biomass was determined in both the in- and between-row sections prior to cover crop incorporation by harvesting a 0.25m2 section of cover crop and drying to constant weight. In a third treatment we added oat straw mulch at a rate of 8,000 kg/ha. We transplanted butternut squash after rye termination in early June. Insect, disease, and weed data were collected throughout the season, with squash to be harvested and yields determined in mid-October. Objective 2. System-level effects of between-row management strategies, including living cover crops, for plasticulture-grown summer squash production. While plastic mulch provides many benefits, the increase in impervious cover in plasticulture fields can lead to greater runoff, leaching, and erosion of the exposed soil between rows. Cover crops grown between plastic mulch beds (living covers) and other strategies to cover the soil surface may promote soil conservation and organic matter improvement while improving fruit quality and pollinator habitat. Field studies were established in Michigan and Wisconsin to gain a more thorough understanding of how between-row management practices influence summer squash production, including crop performance, weeds, pests/beneficials, economics, and nitrogen and soil organic matter dynamics. Treatments included a cultivated control, dead mulch, mowed weeds, cereal rye living mulch, Italian ryegrass living mulch, and a rye/white clover living mulch. Preliminary yield data shows similar squash yields across treatments, while yields of bell pepper (a longer duration crop for comparison) were reduced by all treatments compared to the control. Ongoing analyses are focused on understanding mechanisms leading to these results and evaluating other system-level effects. Obj 3. Nutrient management strategies for plasticulture-grown cucurbits While plastic mulch provides many benefits, the increase in impervious cover in plasticulture fields can lead to greater runoff, leaching, and erosion of the exposed soil between rows. Cover crops grown between plastic mulch beds (living covers) and other strategies to cover the soil surface may promote soil conservation and organic matter improvement while improving fruit quality and pollinator habitat. A field experiment was conducted in MI to evaluate the effects of organic N fertilizer rate (low vs. high), timing (preplant vs. split applications), and plastic mulch use (black plastic mulch vs. bare ground) on slicing cucumber production, as well as evaluating a new downy mildew-resistant cucumber variety (DMR-401 from Mazourek Lab at Cornell). DMR-401 yielded less than our standard variety during a year with no downy mildew pressure. Split applications of an organic N fertilizer through the drip system did not benefit cucumber yields or soil N availability during the season. While plastic mulch maintained higher soil N availability compared to bare ground during the season, cucumber yields were not higher on plastic this year. Field studies were established in Michigan and Wisconsin to gain a more thorough understanding of how between-row management practices influence summer squash production, including crop performance, weeds, pests/beneficials, economics, and nitrogen and soil organic matter dynamics. Treatments included a cultivated control, dead mulch, mowed weeds, cereal rye living mulch, Italian ryegrass living mulch, and a rye/white clover living mulch. Preliminary yield data shows similar squash yields across treatments, while yields of bell pepper (a longer duration crop for comparison) were reduced by all treatments compared to the control. Ongoing analyses are focused on understanding mechanisms leading to these results and evaluating other system-level effects. Obj 4. Cucumber beetle management using perimeter trap crops We created lures using synthetic plant volatiles based on odors released by cucurbit leaves or flowers and hung them inside of hole-punched yellow gallon jugs containing soapy water. Beetles were collected and counted weekly at two vegetable farms in Indiana. Beetles were most attracted to lures imitating flower odors but leaf volatiles were far less attractive. We also detected variation among sites where lures seem to work better at some locations compared with others. In the future we will be evaluating how to augment attraction by combining cucurbit floral odors with a male-produced aggregation pheromone emitted by beetles that may underlie its aggregation behavior. Obj 5. Conduct squash bee survey using citizen science We developed a squash bee survey app that was released to Master Gardeners or anyone interested in the survey. Information about the app and education about bees was done through a webinar, at the Annual Master Gardener meeting, and at two other meetings in Michigan. We received 68 bee survey responses from 24 individuals. Obj 6. Implement organic cucurbit production systems on growers\' farms One of our grower panelists, Jacob Bach, used living cover crops (clover on left two photos) and cover crop mulch (right) in his cucurbit this year. We will be assessing his experiences with these practices during the winter. Obj. 7. Develop extension materials from the project and deliver outcomes to our audience. In March 2017 we conducted a day-long workshop at the Organic Intensives Conference organized by the Michigan Organic Food and Farm Alliance. The workshop included talks on weed, insect and disease management in organic cucurbits. All presentations were recorded and the resulting videos were posted on YouTube, under the MSU Vegetable Extension channel.

We organized a field day in Aug 2017, but it was cancelled due to low registration, instead, we will be holding a webinar this winter. **PUBLICATIONS (not previously reported):** 2016/09 TO 2017/08 1. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Organic Intensives Workshop - Cucurbit insect management. March 9, 2017, East Lansing, MI. 2. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Organic Intensives Workshop - Cucurbit weed management. March 9, 2017, East Lansing, MI. 3. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Organic Intensives Workshop - Cucurbit disease management. March 9, 2017, East Lansing, MI.

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A Multi-regional Approach for Sustained Soil Health in Organic High Tunnels: Nutrient Management, Economics, and Educational Programming

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NON-TECHNICAL SUMMARY

Season-extending high tunnel production has been expanding rapidly across the U.S., offering organic growers an exciting new option for production. High-tunnel production is characterized by increased productivity, but due to intense cultivation strategies, high tunnels pose many challenges for sustainability, soil health, and environmental quality. The long term goal for this integrated project (Research, Education), based on extensive feedback from growers, is to develop a comprehensive and economically viable model to address soil health issues in high tunnels across a wide geographic reach, resulting in increased adoption of practices such as legume cover crop incorporation that promotes sustainable management of organic high tunnels and financial stability for farmers. We propose to evaluate a range of farmer-selected rotations in three distinct regions ranging from the far north to the south, build a predictive understanding of soil quality management and economics of season extension, and facilitate knowledge exchange via University coursework, organic information clearinghouses (hightunnels.org, eOrganic), and community partners (NGOs), with a focused emphasis on limited-resource farmers and historically underrepresented groups. We will develop three organic agriculture course modules, a hands-on short course addressing issues and applicability of high tunnels for limited-resource growers, a mobile nutrient management phone app, and a webinar series. We will also work closely with NRCS\' new Division of Soil Health to connect to existing resources, network farmers, and expand resources via our project results. Our project is designed to have far-reaching implications for how farmers manage their high tunnels for optimal soil health and economic returns.

OBJECTIVES

High tunnel (HT) production has been expanding rapidly across the United States, offering organic growers an exciting, new option for production. High-tunnel production is characterized by increased productivity and protection from extreme weather events and foliar disease. However, because of the intense cultivation strategies, often with large compost additions, HT\'s pose many challenges for sustainability, soil health, and environmental quality. These challenges could offset the economic gains that HT production offers, which is largely unexplored in a holistic way. Thus, our long term goal, based on extensive feedback from growers, is to develop a comprehensive and economically viable model to address fertility and soil health issues in HT\'s across a wide geographic reach, resulting in increased adoption of practices such as legume cover crop incorporation

that promote sustainable management of organic HT\'s and financial stability for farmers. We will accomplish this by conducting networked experiments across a North-South gradient of research sites and by training students and limited-resource farmers excited about using season extension to increase food security and marketing opportunities. Our unique team of researchers and educators is well poised to bring this goal to fruition, with expertise in organic production systems, high-tunnel management, food and agricultural economics, and soil quality. Outcomes include practical, research-based information on conservation and economic benefits of rotations, and allow for improved Organic Systems Plans by broadening viable options for nutrient management and rotation in HT\'s

APPROACH

Advisory Board: We will develop a multi-region advisory board including ten stakeholders from our three sites, compensated for their participation. Our advisory board will meet twice annually, bringing together as many of our members in a face-to-face venue as possibleSoil Quality Experiments: We will develop an extensive research network to guide this project, and also to maintain a high tunnel soil fertility research community that outlives the life of this project. In order to develop recommendations and data that are relevant and useful across a wide geographic range, as part of this project we will develop a community of practice across three climatic zones in the U.S. ranging from cold northern climates in Minnesota (USDA Hardiness Zone 3-4; PD Grossman), the Great Plains in Kansas (Zone 5-6; Co-PD Rivard) and the Mid-South in Kentucky (Zone 6-7; Co-PD Jacobsen). At each site we will develop two associated replicated experiments, designed to 1) model system-level effects of cover crop legume integration (Cropping systems experiment) and 2) identify best establishment practices for soil N acquisition (Cover crop windows experiment).Economic Evaluation Experiments: Together with our economics team, we will assess farmers\' willingness to adopt the proposed nutrient management plans, accounting for economic returns and farmers\' valuation of soil improvements and ecosystem services. This will be accomplished primarily through a partial budgeting approach and a farmer survey. The partial budgeting approach will use data collected from the experiment sites and a phone survey to wholesalers and retailers of local, organic produce. A farmer survey will incorporate a valuation section to elicit farmers\' values for soil resources.Education about High Tunnels: We will facilitate knowledge exchange about high tunnel management to university students and underrepresented groups through new curriculum design and experiential learning. Three hands-on course modules will be developed and shared across existing KY, MN and KS curricula, as well as for use by our collaborating non-profit organizations in each region. We will also develop a unique integrated one-week short course in Appalachia (Eastern KY) for students in all three states to learn about the use of tunnels in under-resourced regions of the U.S. where regular access to fresh and affordable produce is challenging. The field course will be taught as an elective as part of the new University of Minnesota undergraduate Food Systems major and the Kansas State University Urban Food Systems Practicum graduate course, both of which heavily-emphasize experiential learning in food system and agricultural education. A valuable output of our curriculum work is the development of a mobile tool (i.e. \'smartphone app\') to use in our classrooms to help students understand nutrient cycling as related to cover crops, as well as aid farmers in decision-making on their farms. The app will determine the amount of N delivered via a cover crop planting based on common legume N concentrations, recorded biomass or height/density measurements, and rate of N release based on N-release equations under different soil types, temperature, and moisture conditions. The fourth educational tool we will develop is a webinar series in Y4 that will be archived online via the hightunnels.org and eOrganic websites. We will develop a series of three webinars, each describing management practices and lessons learned via our project in each site. **FINAL REPORT** 09/01/16 to 08/31/21 **Outputs** Target Audience: Research results and related resources have been shared with a wide variety of grower groups and students over the life of the project, including Appalachian, Hmong, refugee, indigenous and urban farmers, as well as NRCS and Extension professionals serving these audiences. We estimate to have reached over 1000 individuals via presentations given throughout this five-year project (415 in MN, 425 in KS, and 280 in KY). In addition to this number, we reached 1300 via an NRCS webinar series (see below). During our final (and primary) reporting years of 2019-2021, in-person outreach and visits to the experimental sites was hindered by covid-19, yet expect that we reached significantly more individuals via virtual events. Here we summarize key non-conference events, including field days, classrooms, and workshops. The citations for events from the final product year (2021) are found in the 'Products' and 'Other Products' sections. Other products can be found in past annual progress reports. One of the most important target audiences in this project was NRCS service providers. In 2021, we met our target goal of three national webinars, sharing information with over 1390 attendees and via presentation downloads, 527 of these represented by the final webinar emphasizing soil health data resulting from the project. A second significant educational output from this project was an experiential learning delegation to Kentucky (May-June, 2019) that provided an opportunity for ten students from three states to learn about historical and current challenges and opportunities for sustainable agriculture in Appalachia. Learning opportunities included site visits of historical or commercial importance, and a hands-on

high tunnel build with Grow Appalachia, a local NGO working to promote sustainable agriculture in the region. Every student responding to our post-trip survey reported increased knowledge of Appalachian agriculture, challenges to food access, and high tunnel construction and management. Student comments included: \"I gained so much perspective on Appalachian food systems and on how the general-public understands food systems\" (Student 1); \"I brought ideas and inspirations back to our college farm in hopes of broadening our horizons while simultaneously refining some of our goals. Many ideas and experiences are still ruminating as inspiration that will be utilized as I pursue a career in nonprofits that work with agriculture\" (Student 3). A third important event (February, 2020) was invitation to lead a full-day "Organic University" workshop at the premier organic farming gathering, the MOSES Organic Farming Conference. This 6-hour event included organic farmer Hallie Anderson from Minnesota and three project team members. We reported project results, as well as provided resources and recommendations to 60 organic high tunnel producers. Evaluations demonstrated that 94% of all attendees learned something new, with most informative parts of the program being organizational information, cover crop integration, high tunnel soil nutrient management and environment, pros and cons of different high tunnels, crop rotations and soil health. When asked to rate their knowledge of how high tunnel management affects soils, water, and pests, participants stated "somewhat low to medium" knowledge before the workshop to almost all stating "somewhat high to high" following the workshop. All areas of learning increased participant knowledge in similar ways. Most learning occurred in the areas of cover crop rotations, calculation of fertility benefits, stationary/moveable tunnel differences, and economic management. The project also reached undergraduate and graduate student audiences, and middle and high school students. Three teaching modules based on project research for use in undergraduate level courses were developed covering 1) an introduction to high tunnels, 2) high tunnel rotations and pest management, and 3) soil management. These modules have now been incorporated into existing courses in each state focusing on organic (KY and MN) and urban agriculture (KS). As well as the cross-project outputs above, several significant target audiences were reached in each of our project regions. In Minnesota, we reached a wide diversity of stakeholders, including many non-traditional and BIPOC farmers, via presentations at events such as the Bimaaji'idiwin Gitigaan, a farmer training program on the Fond du Lac reservation (April, 2019), the Great Lakes Indigenous Farming Conferences (Feb, 2020), thee MN Organic Conference in St. Cloud, MN (Jan 2018), the Sustainable Farming Association Conference (March, 2018), and the MOSES Organic Farming Conference (all years). The results from the soil health valuation work were presented at the Joint Meeting of Agricultural and Applied Economics Association and Western Agricultural Economics Association (August 2021). In Kansas across the life of the project, results were delivered to the Juniper Gardens Refugee Training Farm (Kansas City, KS) both formally and informally. Co-PI Rivard collaborated with Juniper Gardens Training Farm Program Manager, Semra Fetahovic, to plant a demonstrational cover crop on their farm. Ms. Fetahovic was given teaching materials and delivered formal instruction on soil health and cover cropping practices to refugee farmers. The work of the project was also delivered during nine field days (one virtual), four workshops, seven regional growers' conferences, and numerous tours and other training events in Kansas. Direct results from the project were delivered to Growing Growers Kansas City Farm apprentices during the soils workshop and vegetable research field day throughout the project period. Growing Growers KC is a beginning farmer apprenticeship program that utilizes workshops and apprenticeships at local organic farms (growinggrowers.org). In Kentucky (University of Kentucky, UK), over the life of the project 29 events reached our target audiences, including presentations to 12 UK courses, 3 field days, 4 regional conferences, 5 state meetings, and 4 county-level meetings. Specifically, results of the project were directly delivered to agriculture service providers (Cooperative Extension Agents, Organic Transition Trainers, and Extension Specialists) at three field day at the University Horticulture Research Farm in Lexington, Kentucky. These events included tours of the field experiments. Producers throughout the Southeastern US were exposed to the project through two sessions (one per year) on high tunnel production and marketing challenges at the Southern Sustainable Agriculture Working Group Annual Conference in Little Rock, Arkansas which incorporated sections on cover cropping challenges and strategies in high tunnels. Conventional and organic producers were exposed to the project in a presentation including project results at the SE Fruit and Vegetable Growers Annual Conference in Savannah, GA. Organic producers, state government officials and service providers in the greater Kentucky area were exposed to the project during a session on Successful Organic High Tunnel Production at the Organic Association of Kentucky (OAK) conference, which was presented by co-PI Jacobsen and a team member from one of our NGO project partners at Grow Appalachia (Mark Walden). Four other state meetings included sessions at OAK Annual conferences and the Kentucky Fruit and Vegetable Grower's Annual conference. Undergraduate students in the UK College of Agriculture, Food and Environment were reached through field and lab activities associated with the Sustainable Agriculture Undergraduate Degree Program. Changes/Problems: Two of our key staff have left the project (Pfeiffer, Gieske), and covid-19 has reduced the pace of laboratory operations. This has slowed progress toward the milestone of peer reviewed manuscript publication reporting on the project. What opportunities for training and professional development has the project provided? Over the 5 project years, the project has supported professional development for two post-doctoral students, two graduate students (UMN and KS), and ten undergraduate students. Dr. Fucui Li, a first post-doc

supported by the project, is now a faculty member in China. Dr. Miriam Gieske, second post-doc researcher, is now an ecology faculty member at the University of Minnesota, Morris. Ashlee Skinner, Master's student at Kansas State University, also finished her M.S. thesis and is now an Extension Associate at the University of Florida. Dojin Park, a PhD student in applied economics, successfully completed his course work and oral prelim during the course of the project. Ammar Al-Zubade and Dr.Debendra Shresth were both research analysts in Jacobsen's lab working on the trace gas aspects of the project. Shresth now a post-doctoral associate at the University of Wisconsin-Madison working on nutrient cycling modeling and N fate. Undergraduate student Ada Fitz-Axen did independent research on spinach production in the project's cover crop windows experiment and presented results at the University of Minnesota research symposium and is currently applying to graduate programs. Finally, at the University of MN and KSU, six additional undergraduates (UMN: Tanner Beckstrom, Martina (Mar) Horns, Kai Leung, Emily Locke, and Heidi Schlinsog; K-State: Cassidy Fleck and Jessica Mascote) learned basic field and lab techniques, introducing them to opportunities in scientific research. One high school student in KS, Luke Lebar, was also trained. While not financially supported by the project, two additional UMN undergraduates (Sarah Duber and Lucia Carlson) and two Macalester College interns (Zala Cok, Talia Berkstrom), were exposed to the project via occasional fieldwork and project reports. Finally, the project provided training to 4 high school students of color from North Minneapolis during a 2d educational program to learn about high tunnel production in Madison, Wisconsin, in partnership with NC-SARE Youth Educator Grant YENC19-137, and Marcus Kar, Program Director of the Youth Farm urban youth development organization in Minneapolis/St. Paul. How have the results been disseminated to communities of interest?Outputs presented in the Products and Target Audience What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? Key findings showed that cover crops produced substantial amounts of biomass and impacted soil nitrogen (N) cycling and associated soil biological characteristics in all three regions. Our results suggest that organic farmers using high tunnels have multiple options to fit a cover crop into their system, however trade-offs exist relative to costs associated with cover crop management and savings provided via cover crop N contribution, and loss of income from cash crop that may be replaced by cover crops. By providing growers with clear data about the soil health, crop yield, and economic considerations posed by cover cropping systems, this project provided data to help farmers better understand these trade-offs. Long term outcomes include knowledge that could serve to reduce detrimental impacts fertilizer overapplication, such as phosphorus run-off, as well as the positive soil health impacts of cover crop inclusion in high tunnel rotations. Goal 1: Across the five years of the project, two experiments were carried out to evaluate the impact of cover cropping systems on soil attributes. Experiment 1 evaluated the degree to which overwintered hairy vetch affected nutrient cycling, biological indicators across the three study sites. Soil mineral N data suggests that within the evaluation period of this study, winter vetch production may result in services related to N retention than N contribution. For example, soil mineral N was generally higher where vetch was not sown relative to the vetch treatment. The hairy vetch cover crop also did not contribute appreciably to mineral N pools four weeks following termination in all site years.While soil mineral N generally trended upwards in the four weeks following vetch cover crop termination, this occurred in all plots including the control where no vetch was sown. Interestingly and in contrast to soil mineral N, at all sites potentially mineralizable N (PMN) was typically higher in the vetch treatment than in the control plots, and frequently increased over the four-week period following cover crop termination. This suggests that while N contributions from vetch may not be apparent in the short-term (4 weeks) following termination, there may be a pool of un-mineralized N that may become available over a longer time frame. No differences were identified in POX-C between plots with vetch those without, yet POX-C trended towards being frequently greater in the vetch treatment than in the control across several site years and sampling periods. Additional soil data (enzyme, PLFA, microbial biomass and soil moisture and temperature) is being analyzed. Two manuscripts are pending, with submission of the first by the end of 2021, and the second soils-focused manuscript by the end of 2022. Experiment 2 (\"cover crop windows\") evaluated the potential of three cover crop scenarios in high tunnels, identifying cover crop species and planting date combinations that produce optimal nitrogen management during narrow windows of planting time in each of our three regions. This experiment includes cover crop and weed biomass samples as soil samples focused more intensely on nitrogen cycling questions. Rotations included 1) warm season summer cover crops (cowpea and cowpea/sorghum sudangrass), 2) winter-killed fall cover crops (millet, and millet/cowpea), and 3) overwintered cover crops (vetch and vetch/rye). In all states, Legume-grass mixtures usually produce more biomass than legume cover crops alone. Mixes often had reduced legume biomass, which likely reduced the N contributed via biological nitrogen fixation. In Minnesota, cowpea/sorghum sudangrass treatment consistently produced the highest cover crop biomass (driven by sudangrass), followed by vetch/rye and cowpea treatments. In all regions, the winter-killed crops of millet, and millet/cowpea, had low biomass relative to the other seasonal windows. Cowpea plots appeared to positively impact available soil N in some regions three weeks after termination and biomass incorporation, with nitrate levels increasing in plots in Minnesota and in Kansas relative to the cowpea/sudangrass mix. An additional project was carried out in KS (graduate student Skinner) to investigate arthropod diversity related to cover crop presence in high tunnels, demonstrating that arthropod diversity was

strongly impacted by soil organic matter content and soil moisture, with mites representing a majority of species present. Results are expected to be submitted for publication by mid 2022. Greenhouse gas emissions results indicate that trace gas flux patterns and cumulative total fluxes differ more by microclimate between the open field and inside tunnels than by practices within the high tunnels. Goal 2: Two economic analyses were performed to quantify farmer valuation of soil health and the financial impact of cover crop use on enterprise returns. A survey developed with a conjoint instrument was finalized after feedback from soil experts and the project advisory board members. The survey was distributed to participants at the 2020 Minnesota Organic Conference and MOSES Organic Farming Conference. Preliminary analysis suggests the survey instrument is effective in estimating values that farmers place on different improvements in soil health. An online version of the survey was designed and distributed to other channels, such as a contact list of farmers at the FairShare Farm and the Organic Broadcaster newspaper at the MOSES, to reach target sample size for reliable statistical analysis. Additional responses were collected during the winter of 2020. In addition to soil and plant data (Goal #1), we compiled economic data for each cover cropping system, including labor inputs and material costs. Data were cleaned to account for differences in sampling and tested using an ANOVA to explore the statistical significance of treatment effects. Data was analyzed using a partial budget method to explore the economic impact of cover crop use on subsequent cash crop returns. Results indicate that the material and labor costs associated with cover crop establishment, maintenance and termination outweighed N fertility benefits, thus producing a negative net change in income for subsequent cash crop enterprises. Negative changes in income were further exacerbated in when the cover crop replaced a winter/early spring cash crop, suggesting that the opportunity costs of cover crop use far outweigh any fertility benefits observed. The economic results have important implications for organic growers who are required under the USDA National Organic Program to incorporate soil building practices, such as cover crops, into their rotation schedule. Two manuscripts are pending, with one submission anticipated by the end of 2021 and another by May 2022. Goal 3: While covid-19 reduced the number of planned events, we were still able to bring results to an estimated 800 individuals, including both virtual and in-person events. The most impactful and high profile of these events was most likely the MOSES Organic University where we reached 60 organic farmers interested in high tunnel production. As part of this event, a 100- page book was developed that included all presentations, as well as numerous additional print resources on high tunnel management. Finally, as a team we updated the hightunnel.org website to include updated resources from multiple sources focusing on high tunnels generally, and more specifically high tunnel soil management. **Publications** - Type: Theses/Dissertations Status: Published Year Published: 2021 Citation: Skinner, A. Monitoring Belowground Arthropods Associated with Cover Crops in Great Plain High Tunnel Systems. 2021 Kansas Rural Center Farm and Food Conference, August 6, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Park, D., Agricultural and Applied Economics Association-Western Agricultural Economics Association Joint Meeting, The Valuation of Soil Health Improvements and Ecosystem Services among Crop Producers in the U.S.,Virtual. (Aug 2, 2021). - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Grossman, J. M., Mid-Atlantic Fruit and Vegetable Convention, \"Improving Soils in High Tunnels with Cover Crops,\" Virtual. (February 9, 2021). - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Grossman, J. M., Great Lakes Fruit, Vegetable & Farm Market EXPO, \"Observing and Assessing Soil Health Indicators on your Farm,\" Virtual. (December 9, 2020). - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Grossman, J. M., Great Lakes Fruit, Vegetable & Farm Market EXPO, \"Virtues of Cover Crops to Support Soil & Crop Health,\" Virtual. (December 9, 2020) - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Locke, E., Gieske, M., Gutknecht, J., and Grossman, J. 2020. Evaluating Enzyme Activity in Agricultural High Tunnels Compared to Open Fields in Minnesota and Kentucky. UMN Undergraduate Research Symposium. Virtual Presentation accessed at Emily Locke.

PROGRESS

2019/09 TO 2020/08 Target Audience:In year 4 of the project, our plans for dissemination of results were greatly impacted by covid-19. Many of our regular venues for presentation, such as the UMN and Southwest Research and Outreach Center\'s organic field days, were cancelled. However, prior to restrictions, we shared our experimental results with organic farmers, indigenous and minority farmers, and Natural Resource Conservation Service (NRCS) staff. We presented the first in a series of three webinars as part of NRCS\' organic agriculture webinar series, with 462 people registering for the webinar and 212 attending. In February, 2020 our project team was honored to be invited to lead a full-day \'Organic University\' event at the premier organic farming gathering in the United States, the MOSES Organic Farming Conference. This 6-hour event included organic farmer Hallie Anderson from Minnesota and three of our project team members. We reported on project results to date, as well as provided resources and recommendations to over 60 organic high tunnel producers. Evaluations demonstrated that 94% of all attendees learned something new, with most informative parts of the program being organizational information, cover crop integration, high tunnel soil nutrient management and environment, pros

and cons of different high tunnels, crop rotations and soil health. When asked to rate their knowledge of how high tunnel management affects soils, water, and pests, participants stated \'somewhat low to medium\' knowledge before the workshop to almost all stating \'somewhat high to high\' following the workshop. All areas of learning increased participant knowledge in similar ways. Most learning occurred in the areas of cover crop rotations, calculation of fertility benefits, stationary/moveable tunnel differences, and economic management. In addition to farmers, the project also reached undergraduate and graduate student audiences, as well as middle and high school students. A series of three teaching modules based on project research for use in undergraduate level courses were developed covering 1) an introduction to high tunnels, 2) high tunnel rotations and pest management, and 3) soil management. In addition, we organized and carried out an experiential learning trip for BIPOC youth to a range of high-tunnel based agricultural enterprises in and around Madison, WI. During the Madison visit, a video was produced highlighting soil health topics specifically relevant to high tunnel environments and innovative high tunnel management strategies, targeted toward college student and farmer audiences. These videos are in the final stages of production. In Kansas, results of the project were delivered to the Juniper Gardens Refugee Training Farm (Kansas City, KS) both formally and informally. Co-PI Rivard collaborated with Juniper Gardens Training Farm Program Manager, Semra Fetahovic, to plant a demonstrational cover crop on their farm. Ms. Fetahovic was given teaching materials and delivered formal instruction on soil health and cover cropping practices to refugee farmers. The work of the project was also delivered during three field days, two workshops, three regional growers\' conferences, and numerous tours and other training events in Kansas. Direct results from the project were delivered to Growing Growers Kansas City Farm apprentices during the soils workshop and vegetable research field day. Growing Growers KC is a beginning farmer apprenticeship program that utilizes workshops and apprenticeships at local organic farms (growinggrowers.org). In Kentucky, results of the project were directly delivered to agriculture service providers (Cooperative Extension Agents, Organic Transition Trainers, and Extension Specialists) at a field day at the University Horticulture Research Farm in Lexington, Kentucky. This event included tours of the field experiments and a demonstration of the app being developed by the project. Producers throughout the Southeastern US were exposed to the project through a session on high tunnel production and marketing challenges at the Southern Sustainable Agriculture Working Group Annual Conference in Little Rock, Arkansas which incorporated sections on cover cropping challenges and strategies in high tunnels. Organic producers, state government officials and service providers in the greater Kentucky area were exposed to the project during a session on Successful Organic High Tunnel Production at the Organic Association of Kentucky conference, which was presented by co-PI Jacobsen and a team member from one of our NGO project partners at Grow Appalachia (Mark Walden). Undergraduate students in the UK College of Agriculture, Food and Environment were reached through field and lab activities associated with the Sustainable Agriculture Undergraduate Degree Program. Changes/Problems:Two of our key staff have left the project (Pfeiffer, Gieske), and covid-19 has reduced the pace of laboratory operations. This has slowed progress toward the milestone of peer reviewed manuscript publication reporting on the project. What opportunities for training and professional development has the project provided?During this reporting period, the project has supported professional development for one post-doctoral student, two graduate students (UMN and KS), and six undergraduate students (in addition to those supported last reporting period). Miriam Gieske, post-doctoral researcher at the University of MN, has learned project management skills, and advanced her knowledge of soil assays and high tunnel field management. In July 2020 Miriam defended her PhD thesis and moved into a faculty position at the University of Minnesota, Morris where she is faculty of Ecology. Ashlee Skinner, Master\'s student at Kansas State University, also finished her M.S. thesis in this reporting period. Dojin Park, a PhD student in applied economics, furthered his understanding of developing an instrument to elicit farmers valuation of soil health. He also interacted with potential respondents as he distributed the survey instrument at MOSES Organic Conference. He also successfully completed his oral preliminary exams using his work on this project as part of his dissertation and became a PhD candidate in applied economics. Ammar Al-Zubade, a PhD student in the Integrated Plant and Soil Science Program at the University of Kentucky successfully completed his written and oral preliminary exams and became a PhD candidate. Dr. Debendra Shrestha, research analyst in Jacobsen\'s lab working on the trace gas aspects of the project, secured a postdoctoral position at the University of Wisconsin-Madison working on nutrient cycling modeling and N fate. Undergraduate student Ada Fitz Axen did independent research on spinach production in the project\'s Experiment two and presented results at the University of Minnesota research symposium. Finally, at the University of MN and KSU, six additional undergraduates (UMN: Tanner Beckstrom, Martina (Mar) Horns, Kai Leung, Emily Locke, and Heidi Schlinsog; K-State: Cassidy Fleck and Jessica Mascote) learned basic field and lab techniques, introducing them to opportunities in scientific research. One high school student in KS, Luke Lebar, was also trained. While not financially supported by the project, two additional UMN undergraduates (Sara Duber and Lucia Carlson) and one Macalester College intern (Zala Cok), were exposed to the project via occasional fieldwork and project reports. Finally, the project provided training to 4 high school students of color from North Minneapolis during a 2d educational program to learn about high tunnel production in Madison, Wisconsin, in partnership with NC-SARE Youth Educator Grant YENC19-137, and Marcus Kar, Program Director of the Youth Farm urban youth

development organization in Minneapolis/St. Paul. How have the results been disseminated to communities of interest?In Minnesota during the 2019-2020 reporting year, in-person outreach and visits to the experimental sites was hindered by covid-19, however one class (HORT 3131) and one organic field day allowed 60 participants, including both university students and the general public, to learn about our project via visits to our experimental sites.Despite the covid-19 restrictions, prior to cancellation of in-person events, we were able to present to live audiences at 12 educational events, including workshops, conference presentaions, and guest lectures. In Kansas, Co-PI Rivard was invited to present at three (virtual) conferences and one webinar on the topic of diversification of high tunnel rotations, including cover crop inclusion. In Kentucky and the Southeast, information about the project was disseminated to an audience of \~250 through field days and conference activities. In particular, at least 45 of these participants were Cooperative Extension Agents or other farm service providers and were exposed to the project in a train-the-trainer capacity. What do you plan to do during the next reporting period to accomplish the goals?Additional outreach efforts will be made to increase the number of responses to the soil health survey. Then, estimates will be incorporated into the enterprise budget analysis to consider the returns to cover cropping practices for various lengths of time. During the final no-cost extension year, we will finish all lab assays. Data analysis has begun and will be completed and compiled in peer-reviewed publications, including six planned for the biophysical data (soils, plants) and two for the economic analysis. We have presented one of the three NRCS Organic webinars. The final two will be taught in the final project year.

2017/09 TO 2018/08 Target Audience:In year 2 of work, we have begun to share preliminary results with grower groups and other stakeholders in a variety of extension programs and professional meetings. Audiences for these programs have been comprised of Appalachian, Hmong, urban, and refugee farmers as well as NRCS and Extension professionals serving these audiences. We have continued ongoing communication with our 9-member Grower Advisory Board including individuals and organizations representing Appalachian, Hmong, urban, and refugee farmers. The Advisory Board has provided critical input into fine-tuning research questions and methodologies and outreach strategies. Changes/Problems:The winter vetch in the cropping systems experiment did not survive the 2017-2018 winter in MN. Since there was effectively no winter cover crop treatment, we reduced our sampling schedule, collecting only spring and fall soil samples. Pending approval for a no-cost extension, we will continue this experiment one addition year to complete three full years of data collection. The planting windows experiment was started in all three sites in the fall of 2017 but experienced setbacks in both MN and KY. In MN, fall planted cover crops had poor germination and minimal winter survival, presumably due to both poor soil quality as well as harsh winter conditions. Topsoil and compost material was added to the MN high tunnel in the spring of 2018, creating a new effective start date for experiment 2. The KY site experienced severe wind storms in April 2018 made the tunnels unsafe for human entry and required significant repair work, resulting in postponement of the experiment until fall of 2018. Pending approval for a no-cost extension, we will continue this experiment one addition year to complete two full years of data collection. What opportunities for training and professional development has the project provided?During this reporting period, the project has supported professional development for 2 post-doctoral students, 1 graduate student and 2 undergraduate students. Post-doctoral students Fucui Li and Miriam Gieske, both post-doctoral students at the University of MN, have learned field experiment management skills as well as soil health lab assays. Ashlee Skinner is a Master\'s student at Kansas State University. Through her work on this project, Ashlee has gained experience developing, collecting and implementing research protocols related to soil health in high tunnels. Ashlee has been successful at teaching these skills to growers as well as K-12 audiences during extension and outreach activities that happen at KSU OHREC. In the summer of 2018, Ashlee attended ASHS to learn more about research methods that are used in horticulture. While there, she also attended an Urban Food Systems Study Tour of Hawaii (not supported by project) to learn about sustainable agriculture methods utilized and food security issues surrounding Urban Agriculture. Undergraduate students Daniel Lee and Natalie Duncan were both employed at the University of MN and learned basic field and lab techniques, introducing them to opportunities in scientific research. How have the results been disseminated to communities of interest?Preliminary results have been shared through a number of field days, conference presentations, and workshops (see \"Other Products\" section for detailed list. In addition to the activities listed above, information from this project has contributed to these other grant-funded projects: Soil Health Bootcamp Workshop held at Schmidt Farms (SARE PDP) Soil Health Bootcamp Workshop held at R&B Produce Farm. Ft. Scott, KS (SARE PDP) J. French, T. Buller, K.Oxley, and C.L. Rivard. 201X. Growing Under Cover: A Kansas Grower\'s Guide. (Volume 3) Kansas Rural Center Publication (40 page manual) (KDA SCBG) J. Vipham, J. DeRouchey, C. Rivard, G. Sampson , and Z. Stewart. 2017 Multidimensional Trade-off Analysis of Integrated Animal-Horticulture Farming Systems for Improved Smallholder Farmer Adoption. (USAID) What do you plan to do during the next reporting period to accomplish the goals?During the next year, field work will continue for both the cropping systems and cropping windows experiemnts, including economic and agronomic data collection. Soil and biomass samples will continue to be analyzed in the lab setting. We have also begun preparing for an experiential learning trip in the summer of 2019 that will bring a dozen undergraduate and graduate students to the Hindman Settlement School, a cultural heritage center in Central Appalachia and other

sites of agricultural and cultural importance in Appalachia as well as offer students a chance to engage in a low-tunnel building process with Appalachian growers. The development of a phone-based app to assit growers and students in understanding cover crop nitrogen credits and improving on-farm decision making is in progress and will be a focus project for the coming year.

2016/09 TO 2017/08 Target Audience:Our activities to date have centered on research that will meet the needs of high tunnel growers, especially limited-resource farmers. High tunnels can provide a sizeable market advantage to growers but must be managed well for soil health in order to remain productive over the long term. The opportunity for high return on high tunnel crops encourages growers to use intensive rotations and may limit opportunities for soil building, especially the use of cover crops. In keeping with the timeline set forth in our original proposal, we will not begin outreach and education activities until later years of the project. We have, however, been mindful about designing research with these growers in mind. We have established a grower advisory board comprised of nine growers or representatives of grower organizations from each of the three regions covered by this project. The Grower Advisory Board includes individuals and organizations representing Appalachian, Hmong, urban, and refugee farmers. Growers have advised project researchers regarding cover crop selection, research needs, and seasonal planting windows during which they are likely to plant cover crops Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?To date, this project has supported professional development for one post-doctoral student and one Master\'s student engaged in conducting field and lab research. Fucui Li has increased her knowledge of field approaches used in organic production through seminars and workshops, and also learned new field and laboratory protocols. Jennifer Nicklay is a Master\'s student at the University of MN in the Department of Soil, Water, and Climate. She has learned field and laboratory research methods and has carried out the soil gas sampling. We also trained an undergraduate student, Justin Panka, who is pursuing an undergraduate degree in Environmental Engineering at the University of Minnesota. Justin learned soil sample preparation and laboratory analyses including quantification of Permanganate oxidizable C (POX-C), Particulate organic matter (POM), and rhizobia occupancy from sampled soil. How have the results been disseminated to communities of interest?The Grower Advisory Board was established and had one full meeting. Individual growers have been consulted to provide input about experimental design related to their personal expertise. Involving this group in the early stages of our research has allowed us to design research that will meet real world needs of growers and provide results that are relevant to their operations. Early in our project two of the PI\'s (Jacobson and Grossman) delivered an NRCS webinar to over 375 live audience members discussing the project objectives. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

IMPACT

2019/09 TO 2020/08 What was accomplished under these goals? High tunnel production has increased dramatically in the United States over the past decade, providing growers with new opportunities for high value production, both in novel crops as well as season extension. Many growers attempt to maximize the profits available in high tunnel crops through intensive cropping, often resulting in long-term soil degradation and environmental consequences. Farmers are interested in learning strategies to improve their high tunnel soil health without compromising their income. In research conducted through this project, summer and overwintering cover crops grown in high tunnels produced substantial amounts of biomass and, in the case of legumes, contributed nitrogen to the system through biological nitrogen fixation. Winter vetch cover crops were able to replace up to 77% of fertilizer N, with no decrease in crop yield relative to fully fertilized plot. Cover crops grown during the summer produced significant biomass and plant-based nitrogen to help reduce the application of external inputs, such as manure, known to contribute to environmental issues such as phosphorus overload in soils. Our results suggest that organic farmers using high tunnels have multiple options to fit a cover crop into their system. By providing growers with clear data about the soil health, crop yield, and economic considerations posed by cover cropping systems, farm systems can become more sustainable, limiting the need and expense for off-farm fertilizer, and reducing the detrimental impacts of overuse of fertilizer, especially phosphorus run-off and losses via GHG emissions. Goal 1: In year four of the project, covid-19 impacted our ability to conduct laboratory analysis, including PoxC, PLFA, and total CN analysis. We anticipate that by spring of 2021 all data will be finalized. We completed field trials for our cropping systems experiment, examining the trade-offs associated with the integration of a winter legume cover crop in rotation with tomatoes, with an emphasis on soil and crop quality, nutrient retention, and cost effectiveness. In this experiment we collected soil samples, weed and cover crop biomass, and produce yield data, as well as labor and other economic inputs to create a systems analysis. We also completed a second replicated field experiment, \"planting windows\" to identify cover crop species and planting date combinations that produce optimal nitrogen management during narrow windows of

planting time in each of our three study regions. This experiment includes cover crop and weed biomass samples as soil samples focused more intensely on nitrogen cycling questions. Experiment 2 (cover crop windows) evaluated the potential of three cover crop scenarios in high tunnels, including rotations of warm season summer cover crops (cowpea and cowpea/sorghum sudangrass), winter-killed fall cover crops (millet, and millet/cowpea), and overwintered cover crops (vetch and vetch/rye). In Minnesota, cowpea/sorghum sudangrass treatment consistently produced the highest cover crop biomass (driven by sorghum sudangrass), followed by vetch/rye and cowpea treatments. Millet, millet/cowpea, and vetch treatments had low biomass. Cowpea plots appeared to positively impact available soil N in some regions three weeks after termination and biomass incorporation, with nitrate levels increasing in plots in Minnesota and in Kansas relative to the cowpea/sudangrass mix. Greenhouse gas emissions results indicate that trace gas flux patterns and cumulative total fluxes differ more by microclimate between the open field and inside tunnels than by practices within the high tunnels. For example, in MN, cumulative nitrous oxide (N2O) fluxes in the high tunnel cover crop treatments were twice that of the open field in 2017 and five times that of open field in 2019. Cumulative CO2 and N2O fluxes in the HT were numerically greater in the continuously cropped (IC) treatment compared to the cover crop (IR) treatment in both 2017 and 2019, but differences were not as pronounced as the open field. Cumulative N2O fluxes in the IC treatment was nearly three times that of IR in 2019. In KY, cumulative trace gas emissions were numerically greater in the HTs than the open field, likely due to high mineral N levels in the soil due to the management history and lack of leaching rainfall for multiple years. However, despite increased greenhouse gas emissions in some HT treatments during some years, yield-scaled global-warming potential (GWP) were lower in HT treatments than the open field in all treatment/site combinations. The GWP is a sustainable intensification measure which adjusts emissions with total crop yields, giving a measure of total emissions per unit yield. Lower yield- scaled GWP values were driven by higher yields in the HTs. Yield scaled GWP was nearly identical in the HT treatments in KY, and was \~40% less than in the open field, on average. Treatment differences were more pronounced in MN, where yield-scaled GWP was 400% greater in the open field than the vetch-based HT treatment in 2017 (open field data were not available for 2019, due to crop failure. Goal 2: A survey developed with a conjoint instrument was finalized after feedback from soil experts and the project advisory board members. The survey was distributed to participants at the 2020 Minnesota Organic Conference and MOSES Organic Farming Conference. Preliminary analysis suggests the survey instrument is effective in estimating values that farmers place on different improvements in soil health. An online version of the survey was designed and distributed to other channels, such as a contact list of farmers at the FairShare Farm and the Organic Broadcaster newspaper at the MOSES, to reach target sample size for reliable statistical analysis. Additional responses will be collected during the winter of 2020. In addition to soil and plant data, we compiled economic data for each cover cropping system, including labor inputs and material costs. Second and third year data were cleaned to account for differences in sampling and tested using an ANOVA to explore the statistical significance of treatment effects. A literature review of cover cropping economics was performed. With the statistical analysis and literature review complete, data from years 1-3 will be analyzed using a partial budget method to explore the economic impact of cover crop use. Results from the analysis will be submitted this winter to a peer-reviewed journal: Agroecology and Sustainable Food Systems or Renewable Agriculture and Food Systems. Goal 3: The literature on soil valuation and measurement of soil health has been reviewed to develop a valuation instrument. The valuation will be included in a longer survey to collect attitudes toward and current practices of soil nutrient management. An earlier version of the survey was reviewed by the advisory board members, and Peterson and a graduate student discussed the survey instrument with each member on the phone. The valuation instrument is continually revised in preparation for its administration. The plan for administration is to invite attendees of a soil health session at MOSES to participate in the survey. While covid-19 reduced the number of planned events, we were still able to bring results to an estimated 800 individuals, including both virtual and in-person events. The most impactful and high profile of these events was most likely the MOSES Organic University where we reached 60 organic farmers interested in high tunnel production. As part of this event, a 100-page book was developed that included all presentations, as well as numerous additional print resources on high tunnel management. Finally, as a team we updated the hightunnel.org website to include updated resources from multiple sources focusing on high tunnels generally, and more specifically high tunnel soil management. **PUBLICATIONS (not previously reported):** 2019/09 TO 2020/08 1. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Gieske, M. F., Grossman, J. M. , Pfeiffer, A., Shrestha, D., Al-Zubad, A., Li, F., Rivard, C. L., Jacobsen, K., Gutknecht, J. L., ASA-CSSA-SSSA International Annual Meeting, \"Cover Crop Effects on Soil Health in Organic High Tunnels,\" San Antonio, Texas. (November 12, 2019). 2. Type: Theses/Dissertations Status: Published Year Published: 2020 Citation: Skinner, A., 2020. Integrating cover crops in high tunnel production systems. M.S. Thesis. Kansas State University. https://krex.k-state.edu/dspace/handle/2097/40667 3. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Rivard, C. Ft. Walton Beach, FL â¿¿Breaking Bad Habits: Integrating Crop Diversity into High Tunnel Production Systemsâ¿¿ Panhandle Fruit and Vegetable Conference, October 2, 2019. 4. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Rivard, C. â¿¿Breaking Bad Habits: Integrating Crop Diversity

into High Tunnel Production Systemsâ¿ Missouri Winter Vegetable Production Conference, Feb 17, 2020, Eureka, MO 5. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Rivard, C. â¿¿Breaking Bad Habits: Integrating Crop Diversity into High Tunnel Production Systemsâ¿. Mid-Atlantic Fruit and Vegetable Conference, January 29, 2020, Hershey, PA. 6. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Fitz-Axen, A., Gieske, M., and Grossman, J. 2020. â¿¿The Effects of Cover Crops on Vegetable Yield and Mineral Nitrogen in High Tunnel Agricultural Systemsâ¿. UMN Undergraduate Research Symposium. Virtual Presentation accessed at Ada Fitz Axen. 7. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Locke, E., Gieske, M., Gutknecht, J., and Grossman, J. 2020. â¿¿Evaluating Enzyme Activity in Agricultural High Tunnels Compared to Open Fields in Minnesota and Kentuckyâ¿. UMN Undergraduate Research Symposium. Virtual Presentation accessed at Emily Locke.

2017/09 TO 2018/08 What was accomplished under these goals? High tunnel production has increased dramatically in the United States over the past decade, providing growers with new opportunities for high value production, both in novel crops as well as season extension. Many growers attempt to maximize the profits available in high tunnel crops through intensive cropping, often resulting in long-term soil degradation and environmental consequences. This work is intended to benefit growers who use high tunnels, or who are considering adding a high tunnel to their operation. Soil health data from the field experiments as well as the economic analysis is intended to provide growers with the resources they need to effectively weigh the costs and benefits of integrating soil building practices into their high tunnel rotation. By providing growers with clear data about the soil health, crop yield, and economic considerations posed by cover cropping systems, farm systems can become more sustainable, limiting the need and expense for off-farm fertilizer, and reducing the detrimental impacts of overuse of fertilizer, especially phosphorus run-off. In year two of the project, we continued field trials for our cropping systems experiment, examining the trade-offs associated with the integration of a legume cover crop in the rotation with tomatoes, with an emphasis on soil and crop quality, nutrient retention, and cost effectiveness. In this experiment we are collecting soil samples, weed and cover crop biomass, and produce yield data, as well as labor and other economic inputs to create a systems analysis. We have completed most lab work and preliminary analysis for the first year of data including both agronomic as well as economic data. We also initiated a second replicated field experiment, \"planting windows\" to identify cover crop species and planting date combinations that produce optimal nitrogen management during narrow windows of planting time in each of our three study regions. This experiment includes cover crop and weed biomass samples as soil samples focused more intensely on nitrogen cycling questions than the cropping systems experiment. Experiment 1 (cropping systems) outcomes In Kansas, both total tomato yield and marketable yield were significantly lower in the Integrated Rotation plots with a vetch cover crop than in the Intensive Control plots. Yield data are not yet available from Kentucky. In Minnesota, the vetch cover crop failed, and thus the effect of cover crops on tomato yield could not be tested. Experiment 2 (planting windows) outcomes In Minnesota, total cover crop biomass was greater in the cowpea/sorghum-sudangrass treatment than in the cowpea treatment, though this difference was only marginally significant. Cowpea biomass was significantly lower in the cowpea/sorghum-sudangrass treatment than in the cowpea treatment. Weed biomass did not differ significantly between treatments. Cover crop biomass data are not yet available from Kansas, and Experiment 2 had to be restarted in Kentucky due to high tunnel structural damage from a storm. Lab analysis of microbial biomass, potentially mineralizable N, and other characteristics of the soil microbial community is underway for all experiment 1 and 2 samples collected in 2018. In addition to soil and plant data, we also collected economic data relative to each cover cropping system, including labor inputs and material costs associated with this system. First year data was analyzed using a partial budget approach to better understand the economic impact of cover crop use in HT systems. 3(a) Major activities completed/experiments conducted: Enterprise data (yield, material input expenses, labor costs) was compiled at each site for year two of the experiment. Net returns were calculated for tomatoes produced using IR and IC treatments using year one data. Net change in income for the cover-tomato and spinach-tomato rotations was calculated to determine the net economic contribution of cover crop treatment using year one data. 3(b) Data collected: Material and labor costs were collected and compiled for cover crops and tomatoes at all three experiment locations. Material costs included seed, inoculants, low tunnel materials, fuel, water, and interest on operating expenses. Labor costs included time spent on tillage and bed prep, planting, irrigation set up and repairs, watering, ventilation and monitoring, low tunnel install and crop termination. Spinach enterprise costs were collected for KS and KY (per original experiment design). 3(c) Summary statistics and discussion of results: Preliminary results suggest no positive economic impact from the use of cover crops. Tomato yields, representing a change in income, show no significant change (positive or negative) following the use of cover crops in the IR treatment. Similarly, the use of cover crops resulted in a very modest reduction in applied nitrogen (due to nitrogen credit observed from cover crop). Therefore, with very little to no added income (tomato yields) or reduced expenses (applied nitrogen), we observed no offset in material and labor costs for the cover crop in year one of the experiment. **PUBLICATIONS (not previously reported):** 2017/09 TO 2018/08 Type: Conference

Papers and Presentations Status: Published Year Published: 2018 Citation: Jacobsen, K. L., MOSES Organic Farming Conference, \"Soil Health in High Tunnels,\" Midwest Organic and Sustainable Education Service, Invited. La Crosse, WI, United States. (February 24, 2018). (No published citation, slides available upon request to confirm acknowledgement of NIFA support.)

2016/09 TO 2017/08 What was accomplished under these goals? High tunnel production has increased dramatically in the United States over the past decade, providing growers with new opportunities for high value production, both in novel crops as well as season extension. Many growers attempt to maximize the profits available in high tunnel crops through intensive cropping, often resulting in long-term soil degradation and environmental consequences. This work is intended to benefit growers who use high tunnels, or who are considering adding a high tunnel to their operation. Data from the field experiments as well as the economic analysis is intended to provide growers with the resources they need to effectively weigh the costs and benefits of integrating soil building practices into their high tunnel rotation. In the first year, the high tunnel (HT) treatments significantly increased the tomato yield and quality, compared with the field best practice (FBP) in MN and KY. In the HTs, tomato yield and quality showed no significant differences between the integrated rotation (IR) and integrated control (IC) treatments in all three experimental sites (MN, KS, and KY). For the cover crop biomass, there was more weed pressure in the HT treatments than in the field in KY. In addition to tomato yield and cover crop biomass measurements, various parameters of soil N and C have been measured to better understand the nutrient cycling under each system for each site at different times. Abiotic measurements include permanganate oxidizable carbon (POX-C), potentially mineralizable nitrogen (PMN), which includes KCl extractable N pools (Ext-N). The results showed that the IR treatment with legume cover crops increased soil POX-C compared with IC treatment at the cover crop termination in KY. Compared with the IC treatment, the IR treatment decreased soil PMN at two weeks after the cover crop termination in MN and four weeks after the cover crop termination in KS, but the IR treatment tended to increase the Ext-N between two and four weeks after cover crop termination at all three sites. Microbial biomass growth and activity strongly mediates nutrients cycling in soils and either builds or degrades soil health. Therefore microbial biomass C and N were also measured . The microbial biomass C and N showed no significant difference between the treatments in three sites in the first year. In addition to soil and plant data, we also collected economic data relative to each cover cropping system, including labor inputs and material costs associated with this system. In the coming year we will analyze this data and build cost benefit models that growers can use to evaluate implementation on their own farms. During this first year of the project, we have developed our experimental design and research protocol. We have now finished collecting data from the first year of the experiment and will analyze this data in the coming months. **PUBLICATIONS (not previously reported):** 2016/09 TO 2017/08 No publications reported this period.

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Understanding Parasite Resistance in Organic Livestock and Using a Systems Approach for Control

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NON-TECHNICAL SUMMARY

One of the greatest barriers to organic production of ruminant livestock is the control of gastrointestinal nematodes (GIN) or parasites. The goals of this project are to 1) understand host mechanisms involved in GIN resistance/resilience by examining differences in immune response among susceptible, resilient, and resistant individuals and breed types, 2) identify genetic loci associated with resistance/resilience, 3) further examine successful systems approaches of GIN control, including fall lambing to minimize summer exposure of GIN to lambs, diverse forage and grazing systems to minimize GIN exposure and use secondary plant compounds for control, and finally, 4) work with farmers enrolled in the National Sheep Improvement Program (NSIP) to understand tools for selection for GIN resistance. Participating farmers will be involved by providing 5000 DNA samples and phenotypes on GIN resistance on lambs in NSIP to use in our objectives. We will educate organic farmers on the importance of NSIP\'s breeding values and elite resistant sires to improve flock genetics for GIN resistance. These goals address OREI Priorities #6 by improving systems based animal production, animal health, and pest (parasite) management practices in the areas of grazing and pasture to improve animal productivity, health and welfare while retaining or enhancing economic viability; and #7 by selecting animal genotypes adapted to organic systems specifically to GIN resistance while grazing organic pasture.

OBJECTIVES

One of the greatest barriers to organic production of ruminant livestock is the control of internal parasites. The long term goals of the project are to 1) understand host mechanisms involved in GIN resistance (the ability to completely resist infection) or resilience (the ability to tolerate an infection without detriment to production) by examining differences in immune response between susceptible, resilient, and resistant individuals and breed types, 2) utilize genomics to identify genetic loci associated with resistance and/or resilience, 3) continue to examine successful approaches of GIN control, specifically lambing in the fall compared with winter/spring, and manipulate forage and grazing systems to minimize GIN exposure, and 4) work with farmers currently enrolled in the National Sheep Improvement Program (NSIP) to understand selection for GIN resistance, and organic farmers on education and adaptation of NSIP in their flocks to enable them to improve genetics for GIN resistance to minimize the need for deworming. These goals address OREI Priorities #6 by improving systems

based animal production, animal health, and pest (parasite) management practices in the areas of grazing and pasture to improve animal productivity, health and welfare while retaining or enhancing economic viability; and #7 by selecting animal genotypes adapted to organic systems specifically to GIN resistance while grazing organic pasture.

APPROACH

Objective 1A: Determine effect of Katahdin sire EBV on H. contortus infection in Katahdin lambs (WVU): In Yr 1 and 2, lambs from high and low GIN resistant sires previously exposed to GIN then dewormed, will be infected with H. contortus to examine infection measures, antibody analysis, and peripheral cell counts for 7 wk post-infection. A subset of lambs will be slaughtered to enumerate worm burden, and run RNA-sequencing, qPCR analysis, and gene expression analysis on abomasal tissue.Objective 1B: Evaluate breed differences in immune responses to different life stages of H. contortus. GIN-free lambs will receive a priming infection of H. contortus, dewormed, rested and circulating immune cells collected and exposed to larval adult and egg stage of H. contortus. Damage to larvae and adults will be assessed by measuring ATP in larvae and adults after exposure to peripheral blood mononuclear cells derived from naïve and primed sheep. Damage to eggs will be assessed by determining egg ability to develop into infective larval stages. In another study, GIN-free lambs will be maintained as naïve lambs to serve as uninfected controls. Primed lambs will be euthanized at either 7 or 28 d following H. contortus infection. Infection measures will be collected and after euthanasia, abomasal contents will be collected and H. contortus larvae and adults will be counted, adult parasites will be sexed and length measurements will be taken. Abomasal tissue will be used for kinomic and RNA-seq analysis, and gene expression. Objective 2. Identification of genetic loci associated with resistance to GIN. DNA from lambs will be run on the OvineSNP50 BeadChip. The genotypes from approximately 54,000 SNP spaced across the genome for all of the selected animals will be collected. We will use PLINK whole genome association analyses software tools and perform a series of genotyping data quality control measures. This includes, but is not limited to, the removal any SNP probes with low genotype quality scores, minor allele frequency below 0.05, as well as any samples not in Hardy Weinberg equilibrium. Following data quality assurances, we will then perform genome association analyses. Objective 3A. Integration of resistant genetics, grazing systems, and season of lambing to control GIN (ARS). Using resistant sires, fall and winter lambing, and a combination of forage systems and management aimed at minimizing off-farm inputs, GIN infection will be determined that will begin in May 2016 (breeding ewes) and continue for the life of this project. In each breeding season, at least 6 rams will be exposed to a minimum of 20 ewes each (n = 120 ewes/season) for 30 d. FEC and body condition score will be determined on ewes at birth, 30 and 60 d post-lambing, body weight at breeding and 30 and 60 d post-lambing, and additional FEC, packed cell volume, and FAMACHA scores on lambs determined every 14 d between 90 and 210 d of age.Objective 3B. Dissecting the forage system to understand minimization of GIN infectivity (FVSU, ARS). Small plots of native legumes and forbs will be established. In mid-July of Yr 3, ungrazed established plots will be used to determine viability of GIN eggs in fecal pellets placed on plots. The aliquots will be scattered in three 30 cm2 random locations within each plot. Herbage samples around fecal material will be collected every 2-3 d. Herbage will be divided into forage species, each cut at 10 cm intervals from base to top of plant to recover, speciate and count larvae. Pioneering effects of the native forage system at the soil level, soil samples at the site of fecal deposition will be collected, baermmanized to collect larvae, and identification of non-GIN and GIN larvae will occur. Concentration and chemical structure of condensed tannins will be characterized in all of the legumes during their vegetative growth period using the thiolysis method.In order to understand how often the native mixes can be grazed, animal performance (GIN infection and growth), native plant mixes of 50% grass will be established in 12 individual 0.4 ha plots. Forages will be grazed at a height of at least 25 cm and will rest for 30 to 45 d or longer. In June of Yr 3, weaned lambs will be rotationally grazed and compared with a conventional rotational pasture system with predominantly tall fescue and/or bermudagrass. FEC, packed cell volume, incidence of deworming, body weight will be measured every 14 d for 120 d. Plant persistence, flowering, pollinator behavior will be observed throughout the study. Forage quality and mass will be determined every 28 d, and soil quality will be determined every 12 mo.Objective 3C. Utilization of Texel sires to improve parasite resistance in an organic farming operation (WVU). We will compare the impact on parasitism of grazing lambs sired by Texel or Suffolk rams over 3 years. Two Texel and 2 Suffolk rams each year would be used to mate 50 ewes per sire breed (25 ewes/sire). All lambs generated by these matings will be evaluated for parasite resistance and gain while grazing. Weight, blood and fecal samples will be collected weekly from June to October and pooled fecal samples will be collected monthly to determine specie of trichostrongylid parasite present on the pastures. At the completion of the study, ultrasonic measurement of fat depth and rib eye area will be performed on all lambs.Objective 4A. Data Collection from the Sheep Industry. Over the four years of the project, pedigree and production data, including EBV on FEC and other production traits will be provided on 5,000 lambs through NSIP on the collaborating Katahdin flocks. Those data will be used to identify (i) high and low FEC EBV rams for use in studies conducted at WVU for defining the mechanisms of immuno-response to a parasite challenge

(Objective 1), and (ii) the 1,250 lambs for genotyping based on their parasite resistance, resilience or susceptibility (Objective 2). Of the animal phenotypes collected, 1250 lambs will be selected for genotyping (for Objective 2B) based on the highest (1/3 of lambs) and lowest (1/3 of lambs) EBV for the Wfec (FEC at weaning or approximately 90 days of age). Another 1/3 of lambs considered to be resilient based on having FAMACHA scores of 1 at sample collection and moderate FEC/Wfec will be included at the resilient group. **Progress** 09/01/16 to 08/31/21 **Outputs** Target Audience:Target audience includes scientists (animal scientists, geneticists), veterinarians, extension specialists, and producers, which were reached through scientific publications and professional meetings, dissemination through websites (www.wormx.info; www.attra.ncat.org), and virtual meetings. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?We provided training to producers on collecting fecal and blood samples from their animals, which not only benefits data collection for the current project but allows them to collect and submit blood for other genotyping or diagnostic analyses. Graduate students at West Virginia University (4), University of Idaho (2), University of Nebraska (1), Fort Valley State University (1), and University of Arkansas in collaboration with USDA, ARS (1 plus undergraduate students) were mentored in techniques necessary to contribute to accomplishments for this project as well as their lifelong professional goals. A series of videos were developed to help producers with techniques for parasite control (www.wormx.info; www.attra.ncat.org). Producers were educated on the benefits of genetic selection for parasite resistance and other important production traits. How have the results been disseminated to communities of interest?Results have been disseminated in scientific meetings (American Consortium for Small Ruminant Parasite Control, COMBAR - the EU equivalent of the ACSRPC, American Society of Animal Science, Southern Section and National; American Association of Veterinary Parasitologists, World Association for the Advancement of Veterinary Parasitology, International Society of Genetics Conference, Plant and Animal Genetic Conference, Entomology Society of America), producer meetings (American Sheep Industry Association Conference, Southern SAWG Organic Research Forum), and webinars (ASI Let's Grow webinar available through YouTube; NSIP webinars on the rollout of genomic enhanced estimated breeding values). Results presented to participating and ancillary Katahdin producers stimulated immense discussion and outcomes which will be used to formulate programs for a wider base of organic sheep and goat producers. Results on parasitology tools developed were presented on the ATTRA website (https://attra.ncat.org) which targets sustainable sheep and goat producers. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? Objective 1) Determine mechanism of action of resistance/resilience to GIN. Katahdin rams selected for high or low fecal egg count (FEC) estimated breeding values (EBV; or parasite) resistance bred to ewes at the Southwest Virginia Agriculture Research and Extension Center in collaboration with WVU, produced lambs from each phenotype without affecting body weight or carcass traits. There was an association between high FEC EBV and compromised immune function in lambs, in that lambs with higher FEC EBV (more susceptible to parasites) appeared to have decreased survival to weaning in lambs either from parasites or other disease. Immune responses differed between resistant and susceptible animals. Interleukin-13, an immune modulator that may be expressed differentially between sheep breeds susceptible or resistant to gastrointestinal (GIN) parasites, is involved in altering mobility of the infective stage larvae of the blood sucking worm, Haemonchus contortus. Monocytes are another immune cell involved in inflammation and when derived from resistant sheep compared with susceptible sheep reduced the energy output of H. contortus larvae. The Texel breed is used for meat production and is known to have establishment of adult GIN worms, but low FEC. This mechanism may be due to an immune response that limits egg laying capacity of the adult worm. These experiments support the use of resistant breeds of sheep for organic production which will greatly reduce the need for deworming and support growth of lambs. Objective 2) Use of industry data and identification of genetic loci associated with resistance to GIN. Collection of phenotypes (fecal egg counts to indicate parasite infection, FAMACHA scores to indicate degree of anemia, and body weights) and 6708 blood cards for DNA analyses on lambs from 23 farms between 2016-2019 occurred and nearly 5000 DNA samples from these lambs with performance data and pedigrees in NSIP (National Sheep Improvement Program) were genotyped using GeneSeek Genomic Profiler Ovine 50K array. We were able to analyze more than the 1250 we anticipated due to a reduction in pricing of the array chips. This also allowed us to genotype an additional 600 samples using the Illumina Ovine Hight Density array that has close to 600K genetic markers. This was used for genome-wide association study analyses (GWAS), the first occurred on a sub-population conducted with FEC EBV revealing significance on five chromosomes and included regions described in published parasite resistance research in sheep. The most significant marker was associated with a gene not previously reported in parasite resistance studies, but known to be under selection in some populations of sheep (DIS3L2). Another GWAS study on 583 sheep using the HD array identified four significant SNP located within the first intron of the gene EGF-like repeats and discoidin domains 3 (EDIL3; has a role in the immune response of inflammation possibly increasing susceptibility to GIN). Sheep with alternate homozygous genotypes had higher FEC compared with all other genotypes. Further studies are needed to understand the role of EDIL3 and genetic mechanisms of susceptibility to GIN. These SNP may contribute to genetic strategies for improving parasite resistance traits in sheep. In

collaboration with the Animal Genetics and Breeding Unit (University of New England, Armidale, Australia) the process for using the genotypes collected to augment prediction of animals' genetic merit (genomic-enhanced Estimated Breeding Values) was validated. The single-step genetic evaluation method was used, which is the most advanced means available to generate genetic predictions. Through the validation process, it was necessary to update heritablities and genetic correlations used in the genetic evaluation. The combined changes led to revised genetic evaluation system delivered through NSIP to Katahdin breeders in October 2021. The genetic diversity of this important breed was captured beyond understanding the genetics of gastrointestinal parasitism and built the foundation of genomic technologies in the U.S. sheep industry. That evolution provides tremendous opportunity for establishing more effective, sustainable, and resilient breeding programs in the U.S. sheep industry which benefit organic production. Objective 3) Examine farm systems that minimize the need for deworming. A multi-year study was completed on finishing fall or winter born lambs on grass pastures either with or without supplement finished to a light weight typical for grass finishing. Winter born lambs required more supplementation due to the poorer quality forages and had greater morbidity related to parasites; fall born ram lambs finished on cool season grasses performed well with or without supplement and had minimal issues with parasites, requiring fewer deworming in fall compared with winter born lambs. Data was collected in multiple years in addition to this study to examine differences in dynamics of GIN in lambs born in fall or winter and seems to indicate that after intense selection for parasite resistance within the flock, GIN infection and amount of deworming may be similar between seasons. Analyses continue on the impact of genetics vs. season which will aid in decisions on parasite management of lambs. A pollinator study was conducted at ARS, Booneville on organic and conventional sheep pastures and pollinator species are being counted and speciated. Decline of insect pollinators which support food production has increased the importance of accurately monitoring pollinator diversity and abundance over time. In organic and conventional sheep pastures, it was determined that differences in color of a passive form of trap in attracting wild bees occurred; bright blue vane traps attracted the highest rate of bees with the greatest diversity relative to other colors (yellow, purple, red) and that bright compared with dark colors attracted more bees. In a related study, bee communities were more diverse and higher evenness observed in non-grazed compared to grazed pastures, possibly due to differences in availability of floral resources that sheep consumed. However, bee abundance and species richness did not significantly differ among grazing treatments. These studies enabled scientists to understand species diversity in sampling wild bees in a livestock pasture setting which is important to entomologists, food scientists, environmentalists, and ecologists. Objective 4) Work with the farmers through extension and NSIP to obtain EBVs on GIN resistance. Much of this was captured in Obj. 2. In addition, impact of our outreach and publications were far reaching. While much of the work focused around the Katahdin sheep breed, it served as a successful model in understanding parasite resistance in organic livestock and that using a system of control is most successful. We were able to convey valuable information to organic and conventional farmers, extension specialists, veterinarians, geneticists, ecologists, and many more through our website (www.wormx.info), ATTRA/NCAT (www.ncat.org), and publications. **Publications** - Type: Journal Articles Status: Published Year Published: 2021 Citation: 1. Weaver, A.R., J.J Garza, S.P. Greiner, S.A. Bowdridge. 2021. Immune response to Haemonchus contortus in Texel sheep. Parasite Immunology 43:e12876.

PROGRESS

2019/09 TO 2020/08 Target Audience:Target audience includes scientists (animal scientists, geneticists), veterinarians, extension specialists, and producers, which were reached through scientific publications and professional meetings, dissemination through websites (www.wormx.info; www.attra.ncat.org), and virtual meetings. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?We provided training to producers on collecting fecal and blood samples from their animals, which not only benefits data collection for the current project but allows them to collect and submit blood for other genotyping or diagnostic analyses. New graduate students learned techniques necessary to contribute to accomplishments for this project as well as their lifelong accomplishments. In addition, a series of videos were developed to help producers with techniques for parasite control (www.wormx.info; www.attra.ncat.org). Producers were educated on the benefits of genetic selection for parasite resistance and other important production traits. ? How have the results been disseminated to communities of interest?Results have been disseminated in scientific meetings (American Society of Animal Science, Southern Section and National; American Association of Veterinary Parasitologists), producer meetings (American Sheep Industry Association Conference), and webinars (ASI Let\'s Grow webinar available through YouTube). Results presented to Katahdin producers stimulated immense discussion and outcomes will be used to formulate programs for a wider base of organic sheep and goat producers. ? What do you plan to do during the next reporting period to accomplish the goals?We will continue to work with farmers to clarify any questions on data submission, and disseminate results of the genomic analyses. Several manuscripts are in progress. We will continue with data analyses and educational and outreach programs as planned.

2016/09 TO 2017/08 Target Audience:Target audience includes farmers andscientists. We are working with farmers from Washington to Georgia and Maine to Texas to collect phenotypic data and DNA from their sheep. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?We provided training to producers on collecting fecal and blood samples from their animals, which not only benefits data collection for the current project but allows them to collect and submit blood for other genotyping or diagnostic analyses. Producers learned how to use the FAMACHA system, a means to estimate parasite infeciton of an animal by the color of the membrane around the eye. New graduate students learned techniques necessary to contribute to accomplishments for this project as well as their lifelong accomplishments. How have the results been disseminated to communities of interest?It is too early in the project to disseminate any results. What do you plan to do during the next reporting period to accomplish the goals?We will continue to work with farmers to collect data and samples to reach our goal of obtaining 5000 DNA samples from lambs with phenotypic data and genetic linkages among several flocks and will include additional farms next year. It is amazing how the National Sheep Improvement Program has grown in terms of determining parasite resistance among lambs within and between flocks to benefit seedstock and commercial farms. Several farmers are aware of how genetics can contribute to parasite management allowing more resistant animals to be free of parasite infections. Projects have begun at West Virginia University, Fort Valley State University, University of Idaho, and ARS according to plan in Objectives 1, 2, and 3 which will allow us to meet goals in Year 2. In addition, graduate students were hired at University of Nebraska, West Virginia University, University of Idaho, Fort Valley State University, and in assocation with ARS to work toward objectives of the project. We will continue with educational and outreach programs as planned.

IMPACT

2019/09 TO 2020/08 What was accomplished under these goals? Objective 1) Katahdin rams selected for high or low FEC EBV (parasite) resistance bred to ewes at the Southwest Virginia Agriculture Research and Extension Center in collaboration with WVU, produced lambs from each phenotype without affecting body weight or carcass traits. There was an association between high FEC EBV and compromised immune function in lambs, which will be explored further outside the scope of the current grant. Objective 2) Collection of phenotypes on lambs from 21 farms between 2017-2019 occurred and 5000 DNA samples from these lambs were genotyped using 50K SNP. An additional 600 samples, including sires of these lambs and select lambs will be genotyped using high density SNP. Farmers submitted phenotypic data on lambs including fecal egg counts to indicate parasite infection among lambs in a contemporary group, FAMACHA scores, and body weights. Analyses using GWAS will occur. In addition, genetic diversity and population structure in Katahdin sheep recorded in the National Sheep Improvement Program (NSIP) is being evaluated. Objective 3) A multi-year study (13 years) was completed on finishing fall or winter born lambs on predominantly grass pastures either with or without supplement finished to a light weight typical for grass finishing. Winter born lambs required more supplementation due to the poorer quality forages and had greater morbidity related to parasites, but fall born ram lambs finished on cool season grasses performed well with or without supplement and had minimal issues with parasites, requiring fewer deworming in fall compared with winter born lambs (Wood et al., 2019). Data has been collected in multiple years to examine differences in dynamics of GIN in lambs born in fall or winter, which will aid in decisions on parasite management of lambs. Results have been analyzed using SAS but several interactions exist that will need to be examined in detail and a manuscript is in preparation. Plots of mixed native forages were established at Fort Valley State University to examine its effects on GIN egg hatch and larval survival in association with more diverse microenvironments compared with monoculture grass plots typical of small ruminant grazing in the Southeastern U.S. Due to the pandemic, research on this objective could not be completed in 2020. A pollinator study was conducted at ARS, Booneville on organic and conventional sheep pastures and pollinator species are being counted and speciated. Manuscripts are expected by early 2021. Objective 4) Phenotypic data and DNA on lambs enrolled in the National Sheep Improvement Program from 21 farms across the U.S. was collected between 2017 and 2019. Data will be used to find genetic markers for parasite resistance, contributing to earlier work that included susceptible and resistant Katahdin sires. Selection of sheep for parasite resistance balanced with maternal traits using estimated breeding values (EBV) and phenotypic traits demonstrated that the ARS and U.S. flocks consistently showed a downward trend (lower fecal egg counts) toward improved parasite resistance over the last 10 years. These sheep are genetically connected to animals from several farms in the U.S. NCAT participated in outreach by producing short videos on what to look for in sheep regarding parasites and health. A Grazing Management video (Part 1 and 2) were available March 2020, a webinar on Managing Internal Parasites (Parts 1, 2, 3) were available on the on the ATTRA website (www.attra.ncat.org). **PUBLICATIONS (not previously reported):** 2019/09 TO 2020/08 1. Type:

Journal Articles Status: Published Year Published: 2020 Citation: Jacobs, J.R., D. Middleton, S.P. Greiner, S.A. Bowdridge. 2020. RNA-sequencing of ovine PBMC after exposure to Haemonchus contortus larval antigen. Parasit. Immunol. https://doi.org/10.1111/pim.12697 2. Type: Journal Articles Status: Published Year Published: 2020 Citation: Middleton, D., J.J. Garza, S.P. Greiner, S.A. Bowdridge. 2020. Neutrophils rapidly produce Th2 cytokines in response to larval but not adult helminth antigen. Parasit. Immunol. https://doi.org/10.1111/pim.12679 3. Type: Journal Articles Status: Published Year Published: 2018 Citation: Jacobs, J.R., S.P. Greiner, S.A. Bowdridge. 2018. Impaired interleukin-4 signaling promotes establishment of Haemonchus contortus in sheep. Parasit. Immunol. https://doi.org/10.1111/pim.12597 4. Type: Journal Articles Status: Published Year Published: 2018 Citation: Garza, J.J., S.P. Greiner, S.A. Bowdridge. 2018. Ovine vital neutrophil extracellular traps bind and impair Haemonchus contortus L3 in a breed-dependent manner. Parasit. Immunol. https://doi.org/10.1111/pim.12572 5. Type: Journal Articles Status: Published Year Published: 2017 Citation: Shepherd, E.A., J.J, Garza, S.P. Greiner, S.A. Bowdridge. 2017. The effect of ovine peripheral blood mononuclear cells on Haemonchus contortus larval morbidity in vitro. Parasit. Immunol. https://doi.org/10.1111/pim.12424 6. Type: Journal Articles Status: Published Year Published: 2017 Citation: Garza, J.J., S.P. Greiner, S.A. Bowdridge. 2017. Serum-mediated Haemonchus contortus larval aggregation differs by larval stage and is enhanced by complement. Parasit. Immunol. http://doi.org/10.1111/pim.12409 7. Type: Journal Articles Status: Under Review Year Published: 2020 Citation: Shepherd, E.A, B. Russ, S.P. Greiner, S.A. Bowdridge. 2020. Interleukin-13 induces paralysis of Haemonchus contortus larvae in vitro. Parasite Immunology 8. Type: Journal Articles Status: Under Review Year Published: 2020 Citation: Shepherd, E.A., S.P. Greiner, S.A. Bowdridge. 2020. Characterization of ovine monocyte activity when cultured with Haemonchus contortus larvae in vitro. Parasite Immunology 9. Type: Journal Articles Status: Under Review Year Published: 2020 Citation: Weaver, A.R., J.J Garza, S.P. Greiner, S.A. Bowdridge. 2020. Immune response to Haemonchus contortus in Texel sheep. Parasite Immunology 10. Type: Journal Articles Status: Under Review Year Published: 2020 Citation: Weaver, A.R., J.M. Burke, J. Morgan, D.L. Wright, S.P. Greiner, S.A. Bowdridge. 2020.Effect of sire fecal egg count estimated breeding value on Katahdin lamb pasture performance. J Anim. Sci. 11. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Weaver, A.R., J.M. Burke, J. Morgan, D.L. Wright, S.P. Greiner, S.A. Bowdridge. 2020.Effect of sire fecal egg count estimated breeding value on Haemonchus contortus infection in Katahdin sheep. J Anim. Sci. 12. Type: Journal Articles Status: Published Year Published: 2020 Citation: Becker GM, Job RJ, Davenport KM, Burke JM, Lewis RM, Miller JE, Morgan JL, Notter DR, and Murdoch BM. Genome-wide association study to identify loci associated with gastrointestinal nematode resistance in Katahdin. Animal Genetics (2020) 13. Type: Journal Articles Status: Published Year Published: 2020 Citation: Davenport KM, Hiemke C, McKay SD, Thorne JW, Lewis RM, Taylor T, Murdoch BM. Genetic structure and admixture from terminal breeds in the United States. Animal Genetics (2020) 14. Type: Journal Articles Status: Under Review Year Published: 2020 Citation: Notter, D.R., Heidaritabar, M., Burke, J.M., Spangler, G.L., Murdoch, B.M., MacNeil, M.D., Morgan, J.L.M., Morota, G., VanTassell, C.P. et al., 2020. 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Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Burke, J.M., 2020. Organic compared with conventional systems for lamb production yield differences in performance in Southeastern U.S. pastures. Southern SAWG Organic Research Forum 19. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Burke, J.M., 2020. Organic and conventional pasture systems for lamb production in Southeastern U.S. J. Anim. Sci. Suppl. 1 (abstr.) 20. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Jones, O., Burke, J.M., Miller, J.E., Rosenkrans, C., 2020. Use of diatomaceous earth and copper oxide wire particles to control gastrointestinal nematodes in lambs. J. Anim. Sci. 98 (Suppl.1 Abstr.). 21. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Burke, J.M., Notter, D.R., Morgan, J.L.M., Miller, J.E., Lewis, R.M., Heidaritabar, M., 2019. Integrating genetic selection with selective anthelmintic treatment to manage gastrointestinal nematodes in Katahdin sheep in the United States. Joint COMBAR/ACSRPC meeting, Ghent, Belgium. P. 74. (abstr.).

2016/09 TO 2017/08 What was accomplished under these goals? While there are no completed accomplishments to date, we began the first year of data and sample collection from 18 farmers from Washington to Georgia and Maine to Arkansas. There will be up to three additional farms next year. Farmers submitted phenotypic data on lambs including fecal egg counts to indicate parasite infection among lambs in a

contemporary group, FAMACHA scores, and body weights. Farmers collected blood samples for DNA isolation for genotyping and GWAS analyses.

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Building Resilience in the Northeast Through Double Cropping and Diverse Forage Crop Mixtures

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Project No.	NYC-125536
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Investigator(s)	Ryan, M. R.

NON-TECHNICAL SUMMARY

Organic dairy farmers in the Northeast have reported challenges with meeting their dry matter and forage nutrient needs due to extreme weather including prolonged periods of flooded soil and short-term droughts. Increasing cropping system diversity can increase yield stability and reduce the negative impact of variable weather. We aim to improve organic agriculture by increasing the adaptive, absorptive, and restorative capacity of organic forage crop production with coordinated multi-state research and extension activities. Guided by our stakeholder advisory board, we will conduct farmer-focused socioeconomic research and field experiments on-farm and at research stations in NY, VT, and NH. We will quantify the productivity and economic viability of intercropping with intra- and interspecific mixtures of winter and summer annual forage crops as part of a double cropping system, and we will compare this double cropping system to perennial-based forage production. Component experiments will assess opportunities for flexible use of forage species included in the double-cropping system. As part of our systems approach, we will also analyze risk management strategies emphasized in organic farming using surveys and interviews of farmers and researchers. We will develop farmer resources on organic forage crop production based on our findings and disseminate this new information through: 1) videos, webinars, and articles on eOrganic, 2) experiential learning activities at field days and farmer workshops, 3) an Organic Forage Crop Production Guide, and 4) newsletter articles. New agroecological curriculum will be developed for an organic agriculture course at UNH and shared with other universities.

OBJECTIVES

Project Goal.Our goal is to improve forage crop production and increase the resilience of organic farming systems in the Northeast (NE) with coordinated multi-state research, extension, and education activities focused on double cropping with winter and summer annual forage crops and intercropping with crop variety and species mixtures.Project Objectives.1. Compare a novel double cropping system to a perennial forage system and quantify the effects of crop diversity on forage yield and quality, soil health indicators, and profitability in the Forage Intercropping for Resilience Experiment (FIRE) in NY, VT, and NH.2. Characterize the human dimensions, including sociological and economic factors that influence forage crop management, and use a mental models analysis to compare farmer and researcher perceptions, values, and approaches to resilience and risk management.3. Create an on-farm research network to optimize the double cropping system tested in the FIRE and work with organic farmers on complementary field experiments at research stations as part of a

comprehensive outreach program that includes a production guide, videos of successful farmers, and hands-on learning activities at field days and workshops.4. Develop lessons on organic forage crop production and deliver a new upper-level undergraduate course at the University of New Hampshire (UNH) focused on quantifying and assessing climate-resilient agroecosystem processes in organic forage cropping systems.

APPROACH

Forage Intercropping for Resilience Experiment (FIRE). We will use a splitplot randomized complete block design with 4 replications. Blocks will be 48 m x 9 m with 12 m buffers between blocks to allow for passage of tractors and equipment. Individual plots will be 6 m x 9 m. All systems will be managed in accordance with NOP rules on certified organic land or land in transition to organic certification. Treatments represent a gradient from low to high diversity in both annual and perennial forage crops. We will compare two management systems: Double Cropping and Perennial Forage. In each system, we will test the effects of forage diversity with four split-plot diversity treatments: A) Low Diversity; B) Intraspecific Diversity; C) Interspecific Diversity; and D) High Diversity.We will work with organic farmers on our advisory board on variety selection and management practices including optimizing seeding rates, seeding dates, seeding depths, and applications of soil amendments (see Letters of Support). Measurements will include forage dry matter yield by crop species, forage crop height and cover at time of harvest, forage quality, weed density and biomass, and soil health. Weeds will be sampled prior to harvest by counting and clipping weeds at the soil surface within two randomly placed 0.5 m2 quadrats in each plot. Scouting procedures for insect and disease pests will be applied in all crops. Weather data will be collected at each research station.We will examine operating costs like fuel, labor, seed price, fertilizer, and maintenance costs at the given price for each respective year the experiment took place. Data for the operating inputs will be collected from original sources, including product receipts. Data on labor and fueluse will also be included in the analysis. Net returns will be estimated based on yield, forage quality, and estimated milk production.Mental Models of Resilience. We will use a mental models analysis to examine methods farmers use to increase absorptive, adaptive, and restorative capacities, and decision-making related to purchasing crop insurance and implementing ecological strategies, such as intercropping and double cropping.Survey of Organic Forage Crop Farmers. We will conduct a large-scale survey of organic farmers in the NE to examine perspectives on resilience and to characterize current use of risk management strategies. A link to the online Qualtrics survey will be e-mailed to farmers throughout the NE.On-farm research will focus on both grazing and haylage production, and all on-farm research and demonstration trials will be done on certified organic land or land that is in transition to organic certification. Treatment details will be developed with farmer participants who serve on our advisory board.Organic Forage Crop Cultivar Evaluation. This research will be conducted at the UVM Borderview Research Farm located in Alburgh, VT.The experimental design will be a randomized complete block with four replicates for all of the variety trials. Short-season corn silage will be established in early June to simulate a double cropping system where triticale is harvested at the boot stage in May. The cool season annual trial will be seeded in mid-August so potential fall and spring forage harvests can be quantified. Sudangrass will be planted in mid-June to simulate establishment after spring grazing of triticale. Plot size will be 2 m x 8 m. The treatments will be established using a walk-behind Carter small seed cone planter. All crops will be sampled at times that would be appropriate for both grazing and haylage harvest. Metrics including date of harvest.Extension. We will use e-mail blasts and newsletter articles to quickly disseminate our results. We will also lead tours of our research plots and report our findings at university field days in each state during each year of the project. During the winter months we will participate in organic farmer workshops and report on our findings at regional events including NOFA Conferences, the VT Organic Dairy Conference, and the New York Organic Dairy Conference. Articles outlining our progress, future activities, and new information generated from this project will be e-mailed to farmers and submitted to newsletters maintained by universities (e.g. Cornell\'s What\'s Cropping Up) and stakeholder groups (e.g. NODPA and NOFA).A semester-long course will be offered each year in the fall semester during project years 2-4 (and potentially beyond) and will be structured into three units, all revolving around the FIRE and component field experiments at the UNH Organic Dairy (ODRF) and Kingman ResearchFarms. Unit one (weeks 1-5) will focus on hypothesis generation and field measurements at the UNH ODRF and Kingman Farms. Unit two (weeks 6-9) will be classroom and computer labbased, and will focus on applying quantitative methods for analyzing and visualizing the data that were collected during the first unit. Unit three (weeks 10-13) will focus on reporting, presentation, and synthesis of the analyzed data.We will use a variety of univariate and multivariate statistics to analyze data collected in this project. Analysis of variance (ANOVA), or analysis of covariance (ANCOVA), will be used for routine hypothesis testing in the research trials. Descriptive statistics will be used to characterize the performance of double cropping and intercropping strategies. Advanced multivariate procedures will be used to examine treatment effects on temporal changes in forage quality, soil health, pest populations, and other ecosystem service parameters. Potential multivariate procedures include nonmetric multidimensional scaling (McCune et al., 2002) to visualize data and partial least squares regression (Carrascal et al., 2009) and structural equation modeling (Grace, 2006) to determine causal

relationships between forage crop diversity, soil health, and socioeconomic variables. Results from data analyses will be interpreted and translated into several \"farmer-friendly\" formats such as interactive spreadsheets and recommendations all made available on eOrganic and other regional websites. In addition, our results will bepublished in several peer-reviewed journals such as Organic Agriculture, Renewable Agriculture and Food Systems, and Agronomy Journal. The adoption rate of new practices will be analyzed through on-farm workshops, workshop surveys, and a post-program evaluation six months after the educational events. Data will be analyzed to determine the impact of new organic forage crop production recommendations on farm viability. **FINAL REPORT** 09/01/16 to 08/31/21 **Outputs** Target Audience:Northeastern small to mid-size dairy farmers, some of whom are certified organic, most of whom graze their cows, which includes members of the New York Amish and Mennonite communities. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project has offered undergraduate student researchers an opportunity to learn about agriculture research within a randomized complete block design framework. PhD student K. Ann Bybee-Finley completed her penultimate year funded by this project. PhD student Uriel Menalled completed and submitted his master's thesis on this project. These students gained experience in study design, developing and refining protocols, and interfacing with stakeholders through demonstrations and field days. Research technicians have gained experience in refining sampling protocols and methods, weed identification, and perennial and annual forage system field maintenance. How have the results been disseminated to communities of interest?Results have been distributed through field days, farmer-advisory board meetings, scientific and farmer conferences, virtual conferences, a bulletin describing the FIRE experiment, and the Sustainable Cropping Systems Lab website. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? Obj 1. 1) The Forage Cropping for Resilience experiment (FIRE) was established in 2016 and completed in 2018 at the research farms in Aurora NY, Alburg VT, and Madbury NH. The experiment compared three approaches to cropping system diversity in annuals and perennials: increase crop cultivar diversity, increase crop species diversity, or increase both cultivar and species diversities. These three strategies were compared against a single species control crop. In 2018, a greenhouse experiment tested crop tolerance to weed pressure as a function of the FIRE annual and perennial diversity systems. In 2019, sites planted corn for a uniformity trial after the FIRE experiment, with four levels of weed pressure treatments. 2) During each year of the FIRE project, we sampled forage systems for crop and weed biomass, weed communities, and forage quality and yield. Soil nitrate was sampled in 2016 and 2018. Corn biomass production, weed community density by species, and corn tissue composition were assessed in the uniformity trial in 2020. The greenhouse experiment grew crop and weed plants in soil from each diversity treatment from FIRE. Weed and crop biomass were quantified. 3) When pooled over sites and years, yield of winter annuals was 12% greater in the high cultivar diversity treatment compared to the single species treatment. In the perennial systems, forage yield was 25% greater and weed biomass was an order of magnitude lower in the high cultivar diversity treatment compared to the single species treatment. Results from the greenhouse experiment indicated a trend in legacy effects in microbe-driven competition, and an effect of nutrients on the yield potential of the sorghum sudangrass crop. For the uniformity trial, diversity treatment had minimal effects on weed-crop competition. Weed seed banks differed by site and system but not diversity treatment and the presence/absence of weeds changed the composition of corn tissue. 4) Key outcomes from FIRE were that annuals were more productive than perennials and more diverse treatments were more productive than less diverse treatments. Strategically selecting species and varieties for specific traits that maximize both functional and response diversity could further enhance the benefits of cropping system diversification. For the uniformity trial, crop diversity had minimal effect on weed-crop competition, although different diversity systems did consistently influence microbial plant-soil feedbacks, crop nutrient uptake, weed communities, and weed-crop competition. In the greenhouse experiment, soil physical and chemical characteristics differed between cropping systems but not diversity treatments. Cropping system legacies influenced weed-crop competition through their combined effect on soil nutrients and microbes. Obj 2. 1) Interviews were conducted with 25 dairy farmers across New York State after IRB training and a qualitative mixed methods course. Outreach FIRE booklets were distributed to the farmers. A grounded network method was deemed more appropriate than the mental models approach and used to analyze the results. 2) Interview questions covered cropping practices, where farmers seek information, familiarity with diversification practices, general demographics, and more. The interviews were recorded and notes taken. 3) Conventional farmers prioritized annual diversification practices and had greater engagement with information sources, whereas organic farmers prioritized perennial diversification practices and had less engagement with information sources. Organic farmers sought information more focused on ecological management, whereas conventional farmers sought greater precision about annual crop diversification practices. 4) The human dimensions of agroecological practices were characterized in regards to sociological factors (attitudes, behaviors) that influence forage crop management. Organic farms had more land in perennial production and greater complexity in their crop rotations, suggesting that regulations focused on crop diversity may be useful for enhancing social-ecological systems resilience in the face of extreme weather. Obj 3. 1) In 2017, a virtual farmer meeting was held across the three

sites to provide insights on the FIRE project. Annual field days at research stations discussed the experiment in an engaging and interactive way. In 2018-2019 we held six workshops for farmer-collaborators and stakeholders. Instructors discussed production of summer and cool season annual forages. Attendees learned how to identify forage species and assess regrowth levels to determine whether stands were ready to be re-grazed. In 2019, thirteen in-person and virtual outreach programs for dairy farmers and other stakeholders were held. Educational webinars were distributed instead of videos. Participants gained an understanding of the roles of cover crops in diversifying agriculture, managing mixtures for forage diets, double cropping and interseeding, grass-fed dairy practices, and season extension. The FIRE experiment was featured on the Sustainable Cropping Systems Lab's website. \"A Guide to Using Annual Forages in the Northeast\" was developed with farmer-collaborators and stakeholders and then distributed. A report, \"Forage Intercropping for Resilience Experiment\", was shared with interviewed farmers. 2) NA 3) NA 4) The comprehensive hands-on learning experiences for farmers were an important corollary to the research station field trials. Costs, tradeoffs, and benefits of grazing options were discussed. Distributing the grower's manual and the forage guide offered farmers an opportunity to implement forage management tactics tested in university research trials. Obj 4. 1) Modules involved hypothesis generation and field measurements using the FIRE experiment and a nearby forage crop experiment at the UNH Research Farm. Module 1 provided an overview of the rationales for each experiment. In Module 2, students developed hypotheses on soil biological conditions and weed population dynamics. In Module 3, students developed hypotheses for how the FIRE treatments affected populations of organisms that feed on weed seeds and then quantified these effects. Students developed hypotheses related to soil biological diversity and beneficial insects and foliar pests in Module 4. Modules 5-12 focused on plant productivity measurements, data analysis and visualization, and interpretation and presentation of results, with an emphasis on how weather events influenced soil responses, as well as weed and crop productivity. 2) NA 3) NA 4) Aspects from the four modules from the new course were integrated into PD Smith's existing agroecology course at UNH (SAFS 502), which he teaches annually to approximately 50 students each year. Due to the COVID-19 pandemic, in fall 2020 the original course could not be offered as planned. Instead, module content was included in a cover crop course through a multi-state Precision Sustainable Agriculture project. Cover crop and annual forage demonstration trials were established in which students can collect data. In fall semester 2021, a new course, SAFS 795/895 \"Investigations\", was taught by PD Smith for the first time. The course will continue to be delivered each fall for the next three years. As part of the course, students pose hypotheses and collect data aimed at understanding how agrobiodiversity drive agroecosystem resilience. The course is field-based, making use of demonstration and experimental field plots that have been established on organically managed land. After studying the material, students will have acquired new skills in conceiving and conducting agricultural experiments, collecting and analyzing agricultural data, and communicating the results of their analyses to their peers. **Publications** - Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Bybee-Finley, KA, L Ruhl, HM Darby, RG Smith, and MR Ryan. 2018. Double-cropping and intercropping in northeastern forage cropping systems to enhance resilience. ASA, CSSA & SSSA International Annual Meeting. ASA Section: Agronomic Production Systems 1085. - Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Bybee-Finley, KA, S Cordeau, and MR Ryan. 2018. Building better cover crop mixes by understanding competition. ASA, CSSA & SSSA International Annual Meeting. ASA Section ASA Section: Land Management and Conservation. 84-1. - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Bybee-Finley, KA, S Cordeau, S Yvoz, SB Mirsky and MR Ryan. 2020. A Framework for Selecting Seeding Rates for Cover Crop Mixtures. ASA, CSSA & SSSA International Annual Meeting. ASA Section: Land Management and Conservation. Virtual event. 131447. - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Menalled, U, CJ Pelzer, and MR Ryan. 2019. Soil-mediated effects on weed-crop competition. ASA, CSSA & SSSA International Annual Meeting. ASA Section: Agronomic Production Systems. 60-9. - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Ryan, MR, MG Ball, AB Jernigan, CJ Pelzer, S Wayman, and CL Mohler. 2019. Lessons from the Cornell organic grain cropping Systems experiment. ASA, CSSA & SSSA International Annual Meeting. ASA Section: Agronomic Production Systems. 60-3. - Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Bybee-Finley, KA, SB Mirsky, and MR Ryan. 2017. Optimizing yield and forage quality of summer annual grass-legume mixtures in the Northeast. ASA, CSSA & SSSA International Annual Meeting. Division: C06 Forage and Grazinglands. 68-118-6. - Type: Conference Papers and Presentations Status: Other Year Published: 2017 Citation: Bybee-Finley, KA, S Mirsky, and MR Ryan. 2017. Assessing competition in warm season intercrops using partial land equivalent ratios. Northeast Cover Crops Council Annual Meeting. Ithaca, NY. - Type: Journal Articles Status: Published Year Published: 2022 Citation: Bybee-Finley, KA, S Cordeau, S Yvoz, SB Mirsky, MR Ryan. 2022. Finding the right mix: a framework for selecting seeding rates for cover crop mixtures. Ecological Applications 32: e02484. - Type: Journal Articles Status: Submitted Year Published: 2022 Citation: 1. Bybee-Finley, KA, MR Ryan, UD Menalled, CJ Pelzer, J Cherney, H Darby, L Ruhl, N Warren, RG Smith, N Lounsbury. Quantifying the roles of intraspecific and interspecific diversification strategies in forage cropping systems. - Type: Journal Articles Status: Published

Year Published: 2021 Citation: Ryan, MR. 2021. Crops better when grown together. Nature Sustainability 4:926-927. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Menalled, UD, KA Bybee-Finley, RG Smith, A DiTommaso, SJ Pethybridge, and MR Ryan. 2020. Soil-mediated effects on weed-crop competition: Elucidating the role of annual and perennial intercrop diversity legacies. Agronomy 10:1373. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Lounsbury, NP, Warren, ND, Wolfe, S, Smith, RG. 2020. Investigating tarps to facilitate organic no-till cabbage production with high-residue cover crops. Renewable Agriculture and Food Systems 35:227-233. - Type: Journal Articles Status: Published Year Published: 2017 Citation: Bybee-Finley, KA, SB Mirsky, and MR Ryan. 2017. Crop biomass not species richness drives weed suppression in warm- season annual grass-legume intercrops in the Northeast. Weed Science 65:669-680. - Type: Journal Articles Status: Published Year Published: 2018 Citation: Bybee-Finley, KA and MR Ryan. 2018. Advancing intercropping research and practices in industrialized agricultural landscapes. Agriculture 8:80. - Type: Book Chapters Status: Awaiting Publication Year Published: 2022 Citation: Smith, R.G., Lounsbury, N.P., Palmer, S.A. (forthcoming) Mechanisms of weed suppression by cover crops, intercrops, and mulches. In Korres, N., Travlos, I., Gitsopoulos, T.K. (Eds) Ecologically Based Weed Management: Concepts, Challenges, and Limitations. Wiley Publishing. - Type: Theses/Dissertations Status: Published Year Published: 2021 Citation: Bybee-Finley, KA. 2021. Crop diversification practices as a strategy to enhance the resilience of farms in the face of extreme weather events. PhD Dissertation. Graduate Field of Soil and Crop Sciences. Cornell University. Ithaca, New York. - Type: Theses/Dissertations Status: Published Year Published: 2020 Citation: Menalled, UD. 2020. Legacy effects of intercrop diversity and crop systems on weed-crop competition. MS Thesis.Graduate Field of Soil and Crop Sciences. Cornell University. Ithaca, New York. - Type: Theses/Dissertations Status: Published Year Published: 2021 Citation: Lounsbury, N. 2021 Cover crop-based no-till for small farms: tradeoffs of termination time, method, and ecosystem services. PhD Dissertation. University of New Hampshire. Durham, NH - Type: Conference Papers and Presentations Status: Other Year Published: 2019 Citation: Amsili, J, S Wayman, H van Es, and MR Ryan. 2019. Roots: an exploration of cover crops belowground. Northeast Cover Crops Council Conference. Beltsville, MD

PROGRESS

2018/09 TO 2019/08 Target Audience:Northeastern small to mid-size dairy farmers, some of whom are certified organic, most of whom graze their cows, which includes members of the New York Amish and Mennonite communities. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project has offered undergraduate student researchers an opportunity to learn about agriculture research within a randomized complete block design framework. Graduate students gained experience in study design, developing and refining protocols, and interfacing with stakeholders through demonstrations and field days. Research technicians have gained experience in refining sampling protocols and methods, and in perennial and annual forage system field maintenance. How have the results been disseminated to communities of interest?Results have been distributed through, field days, farmer-advisory board meetings, scientific and farmer conferences, a bulletin describing the FIRE experiment, and the Sustainable Cropping Systems Lab website. What do you plan to do during the next reporting period to accomplish the goals?Obj 1: Data will be analyzed, summarized, and written up. Obj 2: farmer outreach activities will be further refined and more workshops and field days scheduled for the following season. Obj 3: more dairy farmers will be contacted for interviewing, and interview responses will be qualified and analyzed. Obj 4: the new 12-module course will be offered in fall 2020.

2016/09 TO 2017/08 Target Audience:Northeastern small to mid-size dairy farmers some of whom are certified organic, most of whom graze their cows, which includes members of the NY Amish and Mennonite communities. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The undergraduates all received training in conducting agricultural research. The graduate students gained experience in mentoring undergraduate researchers. How have the results been disseminated to communities of interest?Results have been disseminated though advisory board meetings, field days, and conference presentations. What do you plan to do during the next reporting period to accomplish the goals?We plan to continue to collect data on the field experiment (Obj 1), conduct interviews of farmers and develop a survey for farmers (Obj 2), hold another farmer meeting and present at winter extension meetings and summer extension field days (Obj 3), and further develop undergraduate coursework (Obj 4).

IMPACT

2018/09 TO 2019/08 What was accomplished under these goals? Objective 1. 1) Major activities completed / experiments conducted. The Forage Cropping for Resilience Experiment (initiated in 2016) was completed at the Musgrave Research Farm in Aurora, New York (NY), the Borderview Research Farm in Alburg, VT, and the Kingman Research Farm in Madbury, NH. All sites planted corn for a uniformity trial for the 2019 season. In NY and VT, a surrogate weed was seeded at two levels in addition to a weed-free treatment. A greenhouse experiment tested crop tolerance to weed pressure as a function of the FIRE annual and perennial diversity systems. 2) Data collected; Soil was sampled in September to compare to baseline 2016. Soil nitrate, crop biomass production, and weed communities were sampled. 3) Summary statistics and discussion of results Results from the greenhouse experiment indicate a trend in legacy effects in microbe-driven competition, and an effect of nutrients on the yield potential of a sorghum sudangrass crop. In VT, the four diversity levels yielded similarly across 2017-2018, while the annual plots (\~13000 DM lb/ac) had a higher average yield than did the perennial plots (\~5000 DM lb/ac). In NY in 2017, winter annuals yielded \~4600 DM lb/ac and summer annuals yielded \~3000 DM lb/ac. 4) Key outcomes or other accomplishments realized. Key outcomes from the FIRE experiment were that annuals were more productive than perennials and more diverse treatments were more productive than less diverse treatments. Objective 2. 1) Major activities completed / experiments conducted; The interview guide was finalized and approved by IRB, consent forms and outreach material were made and also approved. Western NY extension staff were contacted to assist with locating dairy farmers willing to be interviewed. A comprehensive list of organic dairy farmers in Western NY was made using the Organic Integrity Database. A code book was constructed to prepare the qualitative data for analysis. Outreach FIRE booklet results were distributed to the interviewed dairy farmers. 2) Data collected; Farmers were contacted by email, telephone, word of mouth, extension agents, affiliated farm services (nutritionists, milk cooperatives). Fourteen interviews have been conducted during this reporting period. The interviews lasted between 1-2 hours and took place at the farmer\'s farm. The interviews were recorded, notes taken during the interview, and setting/characteristics noted. 3) Summary statistics and discussion of results and To date, two interviews have been completely coded and the codebook was found workable. Results are not yet ready at this time. 4) Key outcomes or other accomplishments realized. The interviews are going well, with the researcher able to establish rapport with the farmers. Objective 3. 1) Major activities completed / experiments conducted; Six workshops for farmer-collaborators and other stakeholders were held (see other products section) and at these workshops, attendees learned how to identify grass, legume, and forb species and assess regrowth levels to determine whether or not the stands were ready to be re-grazed. The instructors discussed options for introducing new species and legumes into existing pastures depending on the farm\'s goals and the condition of the pasture. Instructors also discussed production of summer and cool season annual forages that can help supplement perennial pastures to meet dry matter intake needs. Additionally, \"A Guide to Using Annual Forages in the Northeast\" by Heather Darby, Susan Monahan, and Sara Ziegler, is a growers\' guide that is being developed to share with farmer-collaborators and stake-holders. \"Forage Intercropping for Resilience Experiment\", written by Ann Bybee-Finley and Matthew Ryan was shared with 14 dairy farmers that were interviewed in 2018-2019. 2) Data collected; 3) Summary statistics and discussion of results and 4) Key outcomes or other accomplishments realized. Hands-on learning activities for workshops and field days were developed and offered to farmer participants. These included a pasture walk under continuous grazing management in which attendees could see examples of overgrazing damage, perennial and annual weed issues, and identify grass, legume, and forb species. The instructors demonstrated a few methods that could be used to determine the amount of dry matter available in the pasture. They also walked participants through a worksheet detailing how to calculate how much acreage is needed for your herd for 24 hours and how that could be used to create a very basic grazing plan throughout the season for beginning grazers. The instructors discussed the costs, tradeoffs, and benefits of grazing options. Objective 4. 1) Major activities completed / experiments conducted; Dr. Richard Smith has developed four modules for this new course and aspects of these have been integrated into his existing agroecology course at UNH (SAFS 502). These modules involve hypothesis generation and field measurements using the FIRE experiment and a nearby conventionally managed forage crop experiment at the UNH Kingman Research Farm as living laboratories. Module 1 provides an overview of the rationales for each experiment in a \"field-day\" format. In Module 2, students develop hypotheses for how the treatments represented by the FIRE experiment and conventional analog would be expected to affect key soil biological conditions and weed population dynamics. In Module 3, students develop hypotheses for how the FIRE treatments affect populations of organisms that feed on weed seeds (post dispersal weed seed predation) and quantify these effects using seed predation assays and enclosure cages. In Module 4, students develop hypotheses for how the FIRE treatments would be expected to affect soil biological diversity and populations of beneficial insects and foliar pests. Additional modules (Modules 5-12) focus on plant productivity measurements (including forage crop yield), data analysis, data visualization, and interpretation and presentation of results, with an emphasis on how weather events influence measured soil physical, chemical, and biotic responses, as well as weed and crop productivity. 2) Data collected; 3) Summary statistics and discussion of results and 4) Key outcomes or other accomplishments realized. While several of these modules have already been integrated into Dr. Smith\'s

undergraduate agroecology course (SAFS 502) which he teaches annually to approximately 50 students each year, Dr. Smith expects to offer the entire 12-Module course as a new, stand-alone, primarily field-based course in the Fall semester of 2020. **PUBLICATIONS (not previously reported):** 2018/09 TO 2019/08 1. Type: Journal Articles Status: Published Year Published: 2018 Citation: Bybee-Finley, K. A., Ryan, M. (2018) Advancing Intercropping Research and Practices in Industrialized Agricultural Landscapes. Agriculture 8, 80. doi:10.3390/agriculture8060080. 2. Type: Journal Articles Status: Other Year Published: 2020 Citation: Bybee-Finley, KA, J Cherny, SB Mirsky, and MR Ryan. 201x. Annual grass-legume emergency forage crop mixtures across the Northeast. **PROGRESS: 2017/09 TO 2018/08** Target Audience:Northeastern small to mid-size dairy farmers, some of whom are certified organic, most of whom graze their cows, which includes members of the NY Amish and Mennonite communities. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project has offered undergraduate student researchers an opportunity to learn about agriculture research within a randomized complete block design framework. Graduate students gained experience in developing and refining protocols, and interfacing with stakeholders through demonstrations and field days. Research technicians have gained experience in refining sampling protocols and methods, and in perennial and annual forage system field maintenance. How have the results been disseminated to communities of interest?Results have been distributed through farmer-advisory board meetings, field days, conferences, a bulletin describing the FIRE experiment, and the Sustainable Cropping Systems Lab website. What do you plan to do during the next reporting period to accomplish the goals?Obj 1: Data collection will continue within the field experiment. Obj 2: more farmers will be interviewed and interview data will be summarized. Obj 3: a farmer-advisory board meeting will be held December 2018, and presentations will be given at summer field days and winter extension meetings. Obj 4: undergraduate coursework plans will be further developed and refined. UNH should provide a decision on course approval in the winter of 2019. **IMPACT: 2017/09 TO 2018/08** What was accomplished under these goals? Obj 1. 1) Major activities completed / experiments conducted. The Forage Cropping for Resilience Experiment (initiated in 2016) was maintained at the Musgrave Research Farm in Aurora, NY, the Borderview Research Farm in Alburg, VT, and the Kingman Research Farm in Madbury, NH. 2) Data collected; Annual and perennial forage systems in the study were sampled at two harvests each for crop and weed biomass and forage quality. Soil nutrient samples were taken in late summer 2018 to inform plot management. Crop yield was taken with a forage plot harvester. 3) Summary statistics and discussion of results Results from the first year of the experiment indicate that in the perennial system, grasses in the \"high\" and \"very high\" diversity treatments performed much better than did alfalfa in the wet spring of 2017. Average dry matter yield in the perennial plots in 2017 was 2202 lb/ac at the first harvest and 1662 lb/ac at the second harvest. Average dry matter yield for the winter annuals harvested in 2017 was 4663 lb/ac, and average dry matter yield for the summer annuals harvested in 2017 was 3002 lb/ac. In the annual plots, the \"high\" and \"very high\" diversity treatments produced more biomass than \"low\" diversity treatments with only sudangrass. 4) Key outcomes or other accomplishments realized. The major outcome from the first season of data collection and analysis is that the annual system yielded more biomass than the perennial system. Secondly, the \"very high\" diversity treatments yielded more biomass than the \"very low\" diversity treatments in both the annual and perennial systems. Obj 2. 1) Major activities completed / experiments conducted; Ann Bybee-Finley took a qualitative mixed methods course completed in fall 2017 to help inform the structure and methods of conducting and analyzing sociological and economic factors from farmer surveys. 2) Data collected; Five pilot farmer interviews were conducted and recorded. Interview question topics included basic demographics, farm management practices, the extent of farmers\' intercropping/double cropping/cover cropping, and involvement with social and resource networks. 3) Summary statistics and discussion of results and Analysis pending. 4) Key outcomes or other accomplishments realized. The format for interviews has been modified and improved in an iterative approach, based on detailed attention paid to farmer responses in pilot interviews. A grounded network method will replace the original mental models method. Obj 3. 1) Major activities completed / experiments conducted; Project team members were involved in several presentations at the 2017 Northeast Cover Crop Council Annual Meeting, November 4th and 5th at Cornell University. Farmers, researchers, and stakeholders toured the FIRE experiment plots and discussed the forage systems in both NY and VT, at a July 2018 Cornell University field day and a July 2018 University of VT field day, respectively. A farmer-advisory board meeting was held in December 2017. 2) Dta collected; NA 3) Summary statistics and discussion of results and NA 4) Key outcomes or other accomplishments realized. Connections with farmers are being maintained to both inform this research and to provide farmers with management decision resources in the future. Presentations at farmer field days have provided farmers with hands-on opportunities to explore the diversity research plots themselves. A handbook covering experimental design, seeding rates, and first year of results was developed and disseminated to farmers. Obj 4. 1) Major activities completed / experiments conducted; The timeline for delivery of the course is now Fall 2019. In winter 2019 the UNH approvals will be finalized for the new course, and sensors and other associated equipment will be ordered. 2) Dta collected; NA 3) Summary statistics and discussion of results and NA 4) Key outcomes or other accomplishments realized. The syllabus for a new upper-level undergraduate course has been developed and is pending final approval by UNH.

PUBLICATIONS (not previously reported): 2017/09 TO 2018/08 1\. Type: Journal Articles Status: Published Year Published: 2018 Citation: Bybee-Finley, KA and MR Ryan. 2018. Advancing intercropping research and practices in industrialized agricultural landscapes. Agriculture. 8:80. 2\. Type: Journal Articles Status: Published Year Published: 2017 Citation: Bybee-Finley, KA, SB Mirsky, and MR Ryan. 2017. Crop biomass not species richness drives weed suppression in warm-season annual grass-legume intercrops in the Northeast. Weed Science 65:669-680.

2016/09 TO 2017/08 What was accomplished under these goals? Obj. 1: The Forage Cropping for Resilience experiment (FIRE) was established in the fall of 2016 at the Musgrave Research Farm in Aurora, NY; the Borderview Research Farm in Alburg, VT; and the Kingman Research Farm in Madbury, NH. To this point we have collected data on soils, weeds, and forages over two harvests in each of the annual and perennial-based systems (protocols, timing, and agronomic and experimental details vary slightly across the three sites). Obj. 2: IRB training for research on human subjects was completed, the research question has been developed and now qualitative interview questions are taking form. To develop the necessary skills, Ann is taking a qualitative mixed methods course. While initially a mental models methodology was proposed, it was determined to be more appropriate to use a grounded network methodology as the mental models approach frames one group as \"experts\" and the other in need of the information, which mischaracterizes farmer knowledge. Obj. 3: A virtual meeting was conducted in February 2017 across the three sites. This ameliorated some of the travel barriers for farmer participating in scholastic research. Each site hosted their own farmers to discuss the proposed crop rotations, field management, and research questions. Cornell University hosted three farmers from NY, UVM had one from VT, and UNH had one from NH. The FIRE experiment is featured on the Sustainable Cropping Systems Lab\'s website. UVM on its field day had attendees walk around/among the trials where they could touch plants, take photographs, and examine differences of various cultivars and species. Obj. 4: UNH is preparing the paperwork necessary to establish a new field-based course focused on the agroecology of resilient organic forage crop production systems. Syllabi and associated documentation necessary for course approval will be submitted to the university by late fall 2017. The target is to have the approval in place so that the first iteration of the course can be offered fall semester 2018. The course will serve approximately 20 upper-level undergraduates each fall. It is anticipated that most of the students who sign up for the course will be majors in our Sustainable Agriculture and Food System BS program. After taking the course, students will have acquired new skills in conceiving and conducting agricultural experiments, collecting and analyzing agricultural data, and communicating the results of their analyses to their peers. **PUBLICATIONS (not previously reported):** 2016/09 TO 2017/08 No publications reported this period.

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Development of Online Graduate Certificate in Organic Agriculture

Accession No.	1010415
Project No.	ORE00150
Agency	NIFA ORE\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2016-51300-25737
Proposal No.	2016-04469
Start Date	01 SEP 2016
Term Date	31 AUG 2018
Grant Amount	$249,810
Grant Year	2016
Investigator(s)	Jeliazkov, V. Update from CRIS database

NON-TECHNICAL SUMMARY

Organic food production in the United States is expanding rapidly. The sales of organic food and non-food products in the US reached \$39.1 billion in 2014, an increase of 11.3 percent relative to 2013. The sale of organic food accounts for almost 5 % of the total food market in the US. There is an increasing need for graduate training of university students and professionals in Organic Agriculture (OA). Currently in the United States, there is no online master\'s degree program or graduate certificate in OA, whereas undergraduate programs in OA do exist. The goal of this project is to address this gap by the development and implementation of: online certificate in OA for graduate students and professionals across the nation and abroad. After the graduate certificate in OA has been implemented, the next phase will be to build on it and develop an online MSc degree in OA. The project is interdisciplinary and involves instructors, researchers and extension personnel from multiple academic units at Oregon State University (OSU). OSU is among the top 10 universities in the world in the area of Agriculture and Forestry. Also, OSU is one of the top 10 ranking Universities in the US for best online bachelor\'s degree programs. In addition, Oregon has a substantial organic production sector; the certified organic acreage of cropland in Oregon is second in the nation after California. The project objectives fit the 2016 OREI priorities, namely \"8. Develop new undergraduate and/or graduate curriculum in organic agriculture.\"

OBJECTIVES

The project\'s goal is to develop and implement an online graduate certificate program in organic agriculture within the 2-year project period, and then build an online MSc in OA, perhaps in collaboration with another U.S. University, within five years.This project will develop an online Graduate Certificate in OA in several potential areas of specializations: organic whole farm system management, organic livestock management, organic soil management, pest management, perennial berries, fruit crops, vegetables and ornamentals, field crops and forages. This new online graduate certificate will be administered through Oregon State University, consistent with the mission and vision of the institution. This will be achieved through (1) Development of the requirements for the online graduate certificate, (2) Development of new courses, (3) Implementing organic curriculum into some existing courses, and (4) Launching the new online Graduate Certificate at OSU.Specific objectives that were identified to meet the goal of this project are: To evaluate the Oregon State University E-campus market research study to fully assess target audiences and their needs.To develop the Graduate Certificate in OA via planning meetings with project staff and faculty, as well as administrators of the OSU College of Agricultural Sciences (CAS).To develop the Category 1 Proposal for online Graduate Certificate in OA.To develop and deliver courses for the certificate.To market the new online course offerings and Graduate Certificate to potential

students.To evaluate the courses and graduate program outcomes relative to project goals and desired outcomes.To disseminate information and outcomes.The project will address an important educational gap that was identified: the lack of online graduate education in OA. Graduate students, and post-baccalaureate are uniquely positioned as our future scientists, extension agents, public and private executives, and policy makers to have significant influence on policymaking and critical aspects of food security in the next 10-15 years. Educating students in the philosophy and principles of OA would provide them with another decision-making tool when they must assess various environmental, social, and economic factors once they are in the workforce. Overall, a Graduate Certificate in OA will improve production of organic food as well as help meet the demand for educated professionals, policymakers, and general public in the near future. Oregon State University is well suited for the implementation of new Graduate certificate in OA since it has been a leader in providing quality education in agriculture and forestry (ranked in the top 10 worldwide) and in online education (ranked among top 10 in the United States). **FINAL REPORT** 09/01/16 to 08/31/19 Outputs Target Audience:The target audiences include: current graduate students in various agriculture-related programs across the nation that would like to improve their knowledge of OA, professionals in various branches of agricultural entities including certifying organizations, State Departments of Agriculture employees, current extension educators, and post-baccalaureate, who are interested in OA and would like to take online graduate courses. This new online graduate certificate will be available to potential students across the nation and also throughout the world because of the method of online delivery. The courses that were developed as part of this project are available for enrollment in Fall 2019 through the Oregon State University Ecampus https://ecampus.oregonstate.edu/. We organized two meetings with organic growers, professionals, and university faculty, to reach out and discuss what topics should be included in various courses. Developed and distributed 2-pager on the new program. The document was submitted to a number of land-grant universities across the nation and to organic businesses. This action was to reach out (1) graduate students across the nation and (2) organic growers and professionals. Changes/Problems:We did not change any of the goals and the objectives of the approved project. Significant amount of time was needed for the new courses to go through the Oregon State University curriculum proposal system, CATI and CATII processes. There were 15 levels of approval for the new program, the Online Graduate Certificate in Organic Agriculture. Apparently, we underestimated the time needed for the approval of the courses and the new program. Some of the course developments took more time than anticipated. The original project participants were eight (8) of us. However, we involved a number of additional faculty and instructors in the course development. That ensured high-quality of the online courses by tapping into the expertise of a broader course developers. In addition, involving other faculty and staff provided professional development opportunities for everyone involved. At the same time, including additional faculty and instructors caused some delays in new course developments. Therefore, we had to request 1-year no-cost extension. At the end of the day, we achieved the goals and the objectives of the project. In our opinion, we achieved more than promised. What opportunities for training and professional development has the project provided?All project participants and course developers (>20) had to take the online training on course development \"Developing Online Courses\" offered by the Oregon State University Ecampus. This is a required intensive 6-week course designed to help faculty and instructors with the development of online courses. In addition, some of the project participants had the option and have taken \"Teaching Online Classes\" offered by the Oregon State University Ecampus. How have the results been disseminated to communities of interest?The marketing of the new program is an ongoing activity. We are reaching out to current graduate students in various agriculture-related programs across the nation , professionals in various branches of agricultural entities including certifying organizations, State Departments of Agriculture employees, current extension educators, and post-baccalaureate, who are interested in OA and would like to take online graduate courses. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? We accomplished the goal of the project: to develop and implement an online graduate certificate program in organic agriculture. The new program is available now: <https://ecampus.oregonstate.edu/online-degrees/graduate/organic-agriculture/> 12 New graduate courses in Organic agriculture were developed. These include: AGRI 520 Introduction to Organic Food Production CROP 530/SOIL 530 Organic Soil and Crop Management ANS 550 Organic Animal Production Systems AGRI 506 Organic Agriculture Capstone ANTH 586 Anthropology of Food ANS 554 Organic Dairy Farming ENT 548 IPM in Organic Systems ENT 523 Organic Beekeeping and Honey Production FCSJ 554 International Perspectives on Food Systems HORT 540 Organic Vegetable Production Systems HORT 556 Berry Physiology and Production NUTR 525 Organic Food and Health PBG 552 Plant Breeding and Seed Production in Organic Systems In addition, as part of this graduate certificate, we are developing CROP 475/575 Organic Production of Cannabaceae; Hemp and Hops. To our knowledge this will be the first course in the nation or organic production of hemp and hops, and therefore, it is expected to attract much interest. Also, we are working with other uiversity teachers and are offering additional courses as part of the new program, e.g. AGRI 511 Introduction to Food Systems. All specific objectives of the project have been met: Specific objectives that were identified to meet the goal of this project are: To evaluate the Oregon State University E-campus market research study to fully assess target audiences and their needs - Accomplished To develop the Graduate Certificate in OA

via planning meetings with project staff and faculty, as well as administrators of the OSU College of Agricultural Sciences (CAS). - Accomplished To develop the Category 1 Proposal for online Graduate Certificate in OA. - Accomplished To develop and deliver courses for the certificate. - Accomplished To market the new online course offerings and Graduate Certificate to potential students.- In progress, through Oregon State University Ecampus and other means To evaluate the courses and graduate program outcomes relative to project goals and desired outcomes.- Will be evaluated To disseminate information and outcomes. - Will be done once we have run the courses

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Collaborative Release, Tesiting, and Development of Public Sector Multi-use Barley Varieties for Organic Growers

Accession No.	1010431
Project No.	ORE00149
Agency	NIFA ORE\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2016-51300-25731
Proposal No.	2016-04450
Start Date	01 SEP 2016
Term Date	31 AUG 2017
Grant Amount	$44,531
Grant Year	2016
Investigator(s)	Hayes, P.

NON-TECHNICAL SUMMARY

We will conduct a planning grant session in 2016, leading to an OREI proposal in 2017. We will assemble stakeholders from throughout the organic barley value chain in order to identify opportunities and challenges for a new form of the world\'s oldest crop: naked (hull-less) barley. Our long term goal is to provide organic growers, processors, and consumers with a crop, food, and raw material alternative that will be economically rewarding. Currently, organic barley end-uses and markets are stratified due the presence of the adhering hull and grain β-glucan content. Varieties intended for malting/brewing have hulls and low β-glucan due to prevalent brewing techniques. There are brewing technology solutions that allow for capitalizing on the significant advantages of naked barley, provided it has a moderate level of β-glucan. The hull precludes direct food use: it must be removed by pearling, and this process makes the grain ineligible for whole grain status. Therefore, food varieties should be naked, but if they have been bred for high β-glucan content they will be unsuitable for malting and feed. A moderate level of β-glucan can be achieved that will meet FDA guidelines for soluble dietary fiber in human diets and make varieties suitable for brewing and animal feed. Organic feed barley commands a premium, and naked varieties capitalize on this advantage. Our outreach objectives will be to familiarize growers, processors and consumers with the benefits and challenges of naked varieties and to provide guidance for capitalizing on the advantages these varieties offer can offer.

OBJECTIVES

The goal of the planning grant is to bring together stakeholders from throughout the organic barley value chain in order to identify opportunities and challenges for a new form of the world\'s oldest crop: naked (hull-less) multi-use barley. The outcome of the planning grant session will be a full proposal for submission to OREI. Our long term goal is to provide organic growers, processors, and consumers with a crop, food, and raw material alternative that will be economically rewarding and sustainable.

APPROACH

This planning grant evolved from discussions with stakeholders regarding the challenges of incorporating barley into organic production and marketing systems. The greatest challenges identified were the hull and β-glucan content. These factors force segregation and specialization of barleys intended for different purposes. We

identified food, feed, and malt users with interests in developing new products and/or expanding current products involving barley. The discussion expanded to include plant breeders, who shared the status of naked barley germplasm development in their programs, and their enthusiasm for expanding organic breeding. This inclusive dialog revealed that there are naked barley varieties with multi-use potential available, grower willingness to try these varieties, and industry engagement in assessing this grain. Varieties and selections are positioned for release and commercial production at the outset of this grant, and advanced lines following close behind. Additional support for plant breeding, with goals established by stakeholders, will ensure a steady stream of future public varieties. Therefore, it will be possible to immediately proceed to commercialization and assessment and not have to wait while varieties are being developed. The next step in the process was identified as a focused and broad-based discussion amongst stakeholders, researchers, and outreach specialists to chart the most effective path forward for future research. Grant awarded -- see 2017 summary. **Progress** 09/01/16 to 08/31/17 **Outputs** Target Audience: The immediate target audience consisted of representative barley growers, food processors, malt processors, seed producers and researchers. The target audience was engaged from the outset in developing the planning grant concept, as evidenced from the letters of support. A subset of these stakeholders were engaged in the planning grant and were instrumental in developing the plan for continued stakeholder involvement. The participation of outreach specialists was essential in establishing and maintaining target audience involvement. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The session itself provided an on opportunity for training and professional development of all participants via the extensive networking, discussion, and brainstorming. The full proposal will fund a post-doc at OSU (the lead institution) and graduate students at collaborating institutions. How have the results been disseminated to communities of interest?The full proposal led to the formation of a stake-holder advisory committee and extensive national linkages among scientists, farmers, processors, and end-users. These cross-disciplinary and trans-geographic networks will, and have, led to the dissemination of knowledge of, and enthusiasm for, naked barley for organic systems. The concept and execution of the NIFA-OREI supported project will be the focus of an invited chapter in Plant Breeding Reviews - to be published in 2018. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? The Planning Grant session was held in Portland, Oregon November 30 - December 1. The session was attended by 24 scientists and stakeholders. The significant outcomes of the Planning Grant were those proposed: a successful, funded full proposal; an accepted invitation to prepare a chapter for Plant Breeding Reviews on the development of naked multi-use organic barley; and the development of a national network committed to strengthening organic agriculture through naked multi-use barley. Additional relevant details are as follows: The participating scientists included private consultants (economics and malting), Land Grant University scientists (plant breeders, a cereal chemist, and an animal nutritionist). Industry participants included farmers, members of the seed industry, bakers, maltsters, processors, and brewers. Outreach and Extension personnel represented each of the participating states. On day 1, all provided 15 minute presentations, followed by extensive discussion. On day 2, there was continued discussion, formulation of an action plan, and assignment of responsibilities for preparation of the full proposal **Publications** - Type: Journal Articles Status: Accepted Year Published: 2017 Citation: Meints, B., A. Corey, C. Evans, T. Filichkin, S. Fisk, L. Helgerson, A.S. Ross, and P.M. M. Hayes. Registration of Buck Naked Barley. J. Plant Reg. in press.

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Genomic Selection and Crossbreeding for Disease Resistance in Organic Dairy Cows

Accession No.	1010366
Project No.	PENW-2016-04444
Agency	NIFA PENW\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2016-51300-25862
Proposal No.	2016-04444
Start Date	01 SEP 2016
Term Date	31 AUG 2018
Grant Amount	$1,192,110
Grant Year	2016
Investigator(s)	Dechow, C. D.
Performing Institution	PENNSYLVANIA STATE UNIVERSITY, 408 Old Main, UNIVERSITY PARK, PENNSYLVANIA 16802-1505

NON-TECHNICAL SUMMARY

Organic dairy production creates unique challenges that higher innate levels of disease resistance will alleviate. The influences of genotype and breed composition on behavior and fly infestation are also minimally known and could have important implications for both the health of cows and pasture use recommendations. Our goals are to enhance disease resistance in organic dairy cattle through the adoption of optimal genomic selection and crossbreeding strategies and to understand the relationship of genotype to grazing behavior. To do this, we will genotype approximately 2200 Holsteins and 1500 crossbred cattle. Genomic predictions for resistance to calfhood pneumonia, mastitis and other cow disease will be determined for Holsteins. For Holsteins and crossbreds, we will determine A2 beta casein genotype, and obtain genomic predictions for yield traits, productive life, and conformation. Health events and disease will be recorded and associated with genomic predictions. Cows will be visually assessed for measures such as body condition score, we will evaluate behaviors such as bite rate and time until shade is sought, and we will determine fly counts on individual cows. Optimal genetic selection and crossbreeding strategies to enhance herd profitability levels will be established. We will disseminate results to organic dairy producers through workshops, webinars, field days, popular press, and electronic resources. We will also support student training in organic dairy production through the development of new undergraduate curriculum. This project will enhance the appeal of organic dairy production by promoting greater profitability, improving animal welfare, and reduce frustrations associated with managing diseased animals.

OBJECTIVES

Our long term goals are to enhance disease resistance in organic dairy cattle through the adoption of optimal genomic selection and crossbreeding strategies and to understand the relationship of genotype and grazing behavior. This will enhance the appeal of organic dairy production by promoting greater profitability, improving animal welfare, and reduce frustrations associated with managing diseased animals. These goals will be achieved through the following specific research aims. Establish associations of mastitis and cow health with genomic evaluations for specific diseases and general fitness; determine associations of the same characteristics with breed composition in crossbreeding systems. Establish associations of respiratory disease, general health, and growth in organic dairy calves with genomic predictions of respiratory disease resistance, breed composition,

and dam A2 genotype. The incidence of respiratory disease in organic dairy calves and effects of respiratory disease on future performance will be determined. Evaluate the influence of genetic merit and breed composition on pasture behavior and fly infestation and associated health outcomes. We also aim to encourage the adoption of genetic selection and crossbreeding strategies that will enhance the productivity of organic dairy cattle without compromising health and survival. We will do this through the following specific outreach aims.Organic dairy producer outreach through workshops, webinars, field days, popular press, and electronic resources.Student training in organic dairy production through the development of undergraduate curriculum and graduate student research.

APPROACH

We will genotype approximately 2200 Holsteins and 1500 crossbred cattle. Genomic predictions for resistance to calfhood pneumonia, mastitis and other cow disease will be determined for Holsteins. For Holsteins and crossbreds, we will determine A2 beta casein genotype, and obtain genomic predictions for yield traits, productive life, and conformation. Health events and disease will be recorded and associated with genomic predictions. Cows will be visually assessed for measures such as body condition score, we will evaluate behaviors such as bite rate and time until shade is sought, and we will determine fly counts on individual cows. Results will be used to design optimal genetic selection and crossbreeding strategies to enhance herd profitability levels. **Progress** 09/01/16 to 08/31/21 **Outputs** Target Audience:The target audience includes organic dairy farmers and consumers of their products, artificial insemination companies, genomic testing companies, and conventional dairy producers interested in reducing reliance on antibiotics for disease treatment. Changes/Problems:There were some challenges encountered. The animal behavior monitoring halters under research aim 3 required further development to work under field conditions. Due to Covid travel restrictions, field testing was delayed. While the system now works well, our ability to collect and analyze data during the grant timeline was prevented. What opportunities for training and professional development has the project provided?Undergraduate students learned to collect research data on organic calves. One post-doc and five graduate students completed most or all of their research using data they collected on organic farms. More than a dozen research presentations were made by the students at national meetings. How have the results been disseminated to communities of interest?Our research has been reported in dairy farm popular press magazines that have wide distribution plus regional extension publications. Additionally, we have conducted over 20 extension events including field days and online presentations. Our research has also been transmitted to the dairy community through several podcasts available here: https://moosroom.transistor.fm/ What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? Accomplishments under research aim 1. A database with >100,000 cow health records was established using data from 16 organic herds spread across the US. This facilitated several research studies that have been published in peer-reviewed journals and presentations at research conferences. The research highlights have been delivered to the target audience through popular press articles in Hoard's Dairyman which is the most widely distributed dairy farm periodical, and many other extension events, webinars, online presentations, and extension newsletters. The most important conclusions are that: 1.organic cow health is heritable and can be improved through genetic selection and crossbreeding; 2. national genetic evaluations predicted cow health in organic herds moderately well. This suggests that national genetic evaluations derived from conventional herd data is a tool to help lower disease incidence in organic herds. However, using data directly from organic herds would be preferred if a large enough database could be developed; 3. We demonstrated that there are differences among cows in health when confronted with heat stress and developed methodologies to select for improved cow health during heat stress. Accomplishments under research aim 2. A database of calf health was established. We developed a novel trait for genetic selection that will facilitate selection for calves with improved immune function. We demonstrated that genetic selection using national calf health evaluations will help to improve disease resistance; however, large genotype by environment interactions exist and direct selection using data from an antibiotic free management system is required to make optimal genetic progress. Accomplishments under research aim 3. We developed a fly infestation scoring system that can facilitate rapid recording of fly loads on many cows to facilitate genomic selection. The fly scoring system was validated by counting flies in cow pictures. Fly infestation levels are heritable, associated with coat coloration, and genomic regions associated with fly infestation were evident. Cows with heavy fly infestation levels produce less milk than expected. We also improved functioning of an animal behavior halter under field conditions. Under this research aim. Accomplishments under outreach aim 1. Our research has been reported in dairy farm popular press magazines that have wide distribution plus regional extension publications. Additionally, we have conducted over 20 extension events including field days and online presentations. Our research has been transmitted to the dairy community through several podcasts. We have developed and recommended specific breed combinations for crossing in organic systems and have highlighted the potential to use national genomic evaluations for cows health in organic herds. Accomplishments under outreach aim 2. By partnering with the Center for Organic and

Sustainable Agriculture at Alfred State College, undergraduate students learned to collect research data on organic calves. One post-doc and five graduate students completed most or all of their research using data they collected on organic farms. Specialized genetic selection considerations for organic herds have also been woven into existing course material on genetic selection in dairy cattle. **Publications** - Type: Journal Articles Status: Published Year Published: 2022 Citation: Hardie, L.C., I.W. Haagen, B.J. Heins, and C.D. Dechow. 2022. Genetic parameters and association of national evaluations with breeding values for health traits in US organic Holstein cows. J. Dairy Sci. 105. doi:10.3168/jds.2021-20588. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Hardie, L.C., B.J. Heins, and C.D. Dechow. 2021. Genetic parameters for stayability of Holsteins in US organic herds. J. Dairy Sci. 104. doi:10.3168/jds.2020-19399. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Basiel, B.L., L.C. Hardie, B.J. Heins, and C.D. Dechow. 2021. Genetic parameters and genomic regions associated with horn fly resistance in organic Holstein cattle. J. Dairy Sci. 104. doi:10.3168/jds.2021-20366. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Haagen, I.W., L.C. Hardie, B.J. Heins, and C.D. Dechow. 2021. Genetic parameters of passive transfer of immunity for US organic Holstein calves. J. Dairy Sci. 104:20182026. doi:10.3168/jds.2020-19080. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Haagen, I.W., L.C. Hardie, B.J. Heins, and C.D. Dechow. 2021. Genetic parameters of calf morbidity and stayability for US organic Holstein calves. J. Dairy Sci. 104. doi:10.3168/jds.2021-20432. - Type: Theses/Dissertations Status: Published Year Published: 2020 Citation: B. Basiel. Genomic evaluation of horn fly resistance and phenotypes of cholesterol deficiency carriers in Holstein cattle. MS Thesis. Available: https://etda.libraries.psu.edu/catalog/18230blb5624. - Type: Theses/Dissertations Status: Published Year Published: 2021 Citation: I. W. Haagen. Genetic parameters of dairy calf and heifer health. Ph.D. Dissertation. Available: https://etda.libraries.psu.edu/catalog/24151iwh5042 - Type: Theses/Dissertations Status: Awaiting Publication Year Published: 2022 Citation: L. Han. Genetic and phenotypic associations of heat stress with performance, health, survival, and ghrelin concentration in dairy cattle. Ph.D. Dissertation. - Type: Other Status: Published Year Published: 2021 Citation: C.D. Dechow. Fitness genetics improve health on organic farms. HOARDS DAIRYMAN. p710. - Type: Other Status: Published Year Published: 2021 Citation: L. Hardie. National Genetic Evaluations Foster Healthier Organic Cows, too. https://extension.psu.edu/national-genetic-evaluations-foster-healthier-organic-cows-too?j=608496&sfmc_sub=22291110&l=159_HTML&u=14162299&mid=7234940&jb=1001&utm_medium=email&utm_source=MarketingCloud&utm_campaign=DRYT_2021_JULY_EM_GN_DAIRYDIGEST&utm_content=DRYT_2021_JULY_EM_GN_DAIRYDIGEST&subscriberkey=003d000002vHnmJAAS

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Evaluation of Paper Bags for Pest and Disease Management in Organic Peach Production

Accession No.	1010597
Project No.	SC-2016-0440
Agency	NIFA SC.\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2016-51300-25726
Proposal No.	2016-04440
Start Date	01 SEP 2016
Term Date	31 AUG 2020
Grant Amount	$999,770
Grant Year	2016
Investigator(s)	Melgar, J.

NON-TECHNICAL SUMMARY

The production of organic peaches is extremely difficult under the humid conditions of the southeastern U.S due to high pest and disease pressure, and the lack of effective, organically-approved pesticides. This project will provide organic peach growers and growers in transition to organics in the southeastern U.S. with an innovative strategy to increase peach orchard productivity and economic returns, to produce high-quality, low-residue peaches, and to reduce reliance on insecticide/fungicide applications. This project proposes the use of paper bags as a tool to physically protect the fruit from pests and diseases. Our objectives are: 1) To develop an organic production strategy to increase yield of high quality peaches, and long-term farm profitability; 2) To perform an economic assessment of organic/bag versus organic/standard production; and 3) To disseminate this innovative strategy to growers in the southeastern U.S. We will carry out on-farm research in all current and transitioning organic peach farms in South Carolina, Georgia and Florida. We will evaluate fruit quality, yield, packout, and pest and disease incidence during the season in bagged and non-bagged (standard) organic fruit; we wil also conduct economic analyses of organic bagged fruit versus standard organic fruit, including costs and returns models and annual production budgets. Dissemination efforts will include farm visits, local/regional grower meetings, field days, dissemination through an exisiting website and a smartphone app, fact sheets, newsletters, YouTube videos and research papers.

OBJECTIVES

The goal of this project is to provide peach growers in the southeastern United States with a strategy to produce high-quality organic peaches, and to reduce reliance on insecticide/fungicide applications. This project proposes the use of paper bags as a tool to physically protect the fruit from pests and diseases. Thus, the objectives of this project are:To develop an organic production strategy to increase yield of high quality peaches for retail and fresh markets, and long-term farm profitability.To perform an economic assessment of organic/bag versus organic standard production.To communicate results and disseminate this innovative strategy to growers in the southeastern United States.

APPROACH

Research will be carried out on organic farms in three states in the Southeast: South Carolina, Georgia and Florida. Researchers will meet with growers for site selection, and for developing a reduced spray program that focuses on tree pests and diseases (rather than fruit pests and diseases) for the orchards with bagged fruit. Two treatments will be performed: organic standard (non-bagged) peach production and organic bagged-peach production. Different plot sizes will be used for determining the economies of bagging at different scales of operation. In order to assess the efficiency of a reduced spray program in the bagged plot, and associated savings, all fruit in the plot will need to be bagged. Fruit will be bagged immediately after thinning each year, at the beginning of April in South Carolina and Georgia, and in February in Florida. A fungicide/insecticide treatment (sulfur/kaolin) will be applied one day before bagging to largely eliminate pests and pathogens on the fruitlet surface.Fruit pest and disease incidence will be monitored in bagged and non-bagged plots throughout the season. Harvest will take place at commercial ripening stage. Removal of bags prior to harvest would be too time consuming and may lead to a significant amount of unwanted, mature fruit drop. Instead we will ask pickers to carefully rip open all bags from the fruit end at at first picking. This will allow pickers to assess fruit for picking during harvest (since this is a practice that requires cost-benefit analysis, it will be done in all the bagged trees of two experiments). Yield, fruit quality, pest and disease incidence will be assessed before bagging, at harvest and postharvest. Samples will be taken for fruit quality analyses (fruit size and weight, maturity level, brix, TA, color), pest damage and postharvest disease assessments. An economic analysis of the two systems of organic/bag versus organic standard will be performed. A costs and returns model will be developed to analyze the economic profitability of organic peach production comparing the two strategies for production in the Southeast. **FINAL REPORT** 09/01/16 to 08/31/21 **Outputs** Target Audience:Fruit tree growers, including organic fruit tree growers, growers in transition to organics, and conventional growers with potential interest on transitioning to organics, and organic vegetable growers with a potential interest in growing fruit trees. Researchers Extension agents General public Changes/Problems:During the project, there were some years that we could not use the field trials in some locations because their crop was destroyed by freeze damage. Nevertheless, we always had other orchards in other states that were not impacted. In 2020, we could not perform in-person consumer surveys but we did them online using social media outlets and were successful at reaching out to an appropriate number of participants and collect the information we needed. What opportunities for training and professional development has the project provided?Throughout the duration of this project, we have had several presentations to growers such as those given at the UF/IFAS Emerging Agricultural Enterprises Summit: Crops, Livestock and Aquaculture, and stone fruit field days, Southern Sustainable Agriculture Working Group, or the Organic Agriculture Research Forum (organized by the Organic Farming Research Foundation). Students also presented their research as seminars to Extension agents and other graduate students to educate them and train them about this practice. How have the results been disseminated to communities of interest?Results have been disseminated to communities of interest through an eOrganic article, presentations at the Organic Agriculture Research Forum, the Southern Sustainable Agriculture Working Group Conference, the UF/IFAS Emerging Agricultural Enterprises Summit, and scientific conferences such as the American Society for Horticultural Science (both national and regional conference, several years). Furthermore, results have been disseminated through research articles, blogs, factsheets and press releases, as described in the Products section. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? The addition of paper bags to the farm's pest management program could allow organic farmers to grow peaches profitably and sustainably in the southeastern U.S. Paper bags are a physical barrier that can significantly reduce incidence and severity of damage caused by insect and disease pests, especially for those that farmers do not have efficacious OMRI approved formulations. Using paper bags, high-quality organic peaches can be produced even under the high pest and disease pressure conditions of the southeast. Bags do not increase tree yield but increase the percentage of marketable fruit as they reduce the amount of fruit injured by pests and diseases. While bagging increases labor costs, we are seeing how the main impediment in adoption of bagging as a strategy used at large commercial peach farms is not labor cost per se but the availability of labor. Our consumer surveys indicated consumer willingness to pay for bagged organic peaches (i.e. peaches that have not received organic pesticides after bags were placed, about a month after bloom) allows the grower to cover costs (including labor) and sell at a higher price than non-bagged peaches; however, most large commercial peach growers in the southeastern U.S. do not have the workers needed to bag a large acreage as they mostly depend on H2A laborers, and they do not decide the number of H2A laborers needed just for one activity (in this case, bagging) but for the entire crop season. On the contrary, we saw how small growers that run family-owned farms are much more open to adopt this strategy, as they can bag fruit based on local labor that is hired for specific periods of time. For the same reason, and also because of the consumer interest in this type of product seems to be greater at farmer markets, we foresee bagged peaches can preferentially reach local farmer-markets where growers can also get a better price for their produce. Research was conducted at the University of Florida (UF), University of Georgia (UGA), and Clemson University (CU). These research studies included on-farm projects and consumer surveys carried out throughout these states. As a result, one doctoral dissertation (UF), one master's thesis (CU), scientific papers, numerous student

presentations at scientific and grower conferences (some of the students received awards for their presentations), blogs and news releases in different outlets throughout the southeastern U.S. were produced. While the project already ended, a factsheet is also currently being produced. **Publications** - Type: Journal Articles Status: Published Year Published: 2021 Citation: Campbell, D., Brecht, J.K., Sarkhosh, A., Liburd, O. and Treadwell, D. 2021. Photoselective-light impacts on fruit bagging microclimate, quality, and nutrients of peach. HortScience, 56(11): 1354-1362 - Type: Theses/Dissertations Status: Published Year Published: 2021 Citation: Campbell, D. Optimization of cultural practices to improve tree fruit quality and yield in Florida. University of Florida. March 2021. - Type: Websites Status: Published Year Published: 2020 Citation: http://blogs.ifas.ufl.edu/news/2021/10/25/uf-study-place-bags-on-peaches-to-help-keep-pests-diseases-away/ - Type: Other Status: Published Year Published: 2021 Citation: Article in a trade (grower) magazine: https://www.growingproduce.com/fruits/letting-a-healthy-peach-crop-out-of-the-bag-literally - Type: Theses/Dissertations Status: Accepted Year Published: 2020 Citation: Kule, A.K. Fruit Bagging: a Small-Grower and Consumer Horticultural Practice across The Southeastern United States. Clemson University. November 2020. - Type: Journal Articles Status: Submitted Year Published: 2022 Citation: Kim, J., Melgar, J.C., Adhikari, K. and Chavez, D.J. Comparing Bagged Organic Peach to Regular Organic Peach in the Southeastern United States through Consumer Responses. HortScience. - Type: Journal Articles Status: Submitted Year Published: 2022 Citation: Kule, A.K. and Melgar, J.C. Consumer Perception and Willingness to Pay for Organic Bagged Peaches. Journal of Extension. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Campbell, D., Sarkhosh, A., Brecht, J., Gillett-Kaufman, J.L., Liburd, O., Melgar, J.C. and Treadwell, D. 2020. Bagging Organic Peaches Reduces Physical Injuries and Storage Decay with Minimal Effects on Fruit Quality. HortScience, 56(1): 52-58.

PROGRESS

2019/09 TO 2020/08 Target Audience:Fruit tree growers, including organic fruit tree growers, growers in transition to organics, and conventional growers with potential interest on transitioning to organics, and organic vegetable growers with a potential interest in growing fruit trees. Researchers Extension agents General public Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Furthermore, a presentation titled \"Organic Peach Production\" was given at theUF/IFAS Emerging Agricultural Enterprises Summit: Crops, Livestock and Aquaculture on 9 December 2019 in Gainesville, FL to 45 UF/IFAS Extension faculty and agents who participated in the organic track. The UF Stone fruit field day that was originally scheduled for April 28, 2020 was cancelled due to COVID-19, but we look forward to participating at future field days. How have the results been disseminated to communities of interest?Results have been disseminated to communities of interest in 2019-2020 through the eOrganic article, presentations at the Organic Agriculture Research Forum, the Southern Sustainable Agriculture Working Group Conference, the UF/IFAS Emerging Agricultural Enterprises Summit, and scientific conferences. What do you plan to do during the next reporting period to accomplish the goals?An article titled \"Comparing bagged to unbagged organic peach in the Southeastern United States through consumer responses\" will be submitted to HortScience by the end of August or the beginning of September, 2020. This work was primarily carried out at the University of Georgia by a graduate student under the supervision of Co-PI-Chavez. An extension fact sheet \"Organic Peach Production in Florida\" written for small and mid-size producers who are certified organic or who desire to use organic practices is in development for submission to the UF/IFAS Extension fact sheet library (https://edis.ifas.ufl.edu/). All EDIS publications are subject to blind peer review. PI-Melgar and Florida Co-PI-Treadwell met with their graduate students on 14 May 2020 by videoconference to discuss best practices to present peach bagging research to small producers and backyard growers. PI-Melgar and graduate student will write a fact sheet on the use of paper bags in organic peach production. Co-PI-Treadwell and graduate student are planning to provide programming via short videos for stakeholders in Florida that are interested in organic peach fruit production.

2016/09 TO 2017/08 Target Audience:The target audience of this project during the first year was 1) the organic growers interested in participating in the project, and 2) the general public. Efforts included discussing the project goals and objectives, and planning measurements and field work with organic growers on one-on-one meetings, and releasing press articles on the impact of this project on peach organic production in the Southeastern U.S. Changes/Problems:In March 2017 we had three nights with freezing temperatures in the mid and low 20\'s (F) and that in some of the locations where we have experimental fields went down to 19 F. This happened after fruit had set, thus killed 90% of the fruitlets. As a consequence, we were not able to bag fruit. We are planning to request and no-cost extension to get one more year of data since this year we were not able to get them. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest?Outreach articles featuring this research have been

written in different grower magazines, especially magazines for fruit tree growers, for instance in \"The Peach News\". What do you plan to do during the next reporting period to accomplish the goals?Since we have not been able to collect much data this first year because of the freeze, we are planning to request a no-cost extension to make up for the data we have missed this year. In any case, next year we are planning to carry out the field experiments, measure fruit quality, marketable yield,effect on pest and disease reduction, consumer acceptance, and farm profitability. Likewise, we plan to continue doing outreach efforts to inform organic growers, growers in transition to organic production, conventional growers and general public on the possibilities of increasing peach organic production in the Southeastern U.S. by using paper bags for protecting the fruit.

IMPACT

2019/09 TO 2020/08 What was accomplished under these goals? The addition of paper bags to the farm\'s pest management program could allow organic farmers to grow peaches profitably and sustainably in the southeastern U.S. Using paper bags, high-quality organic peaches can be produced even under high pest and disease pressure conditions of the southeast. Bags do not seem to increase tree yield but increase the percentage of marketable fruit as they reduce the amount of fruit injured by pests and diseases. While bagging increases labor costs, we are seeing how the main impediment in adoption of bagging as a strategy used at large commercial peach farms is not labor cost per se but the availability of labor. Our consumer surveys indicate consumer willingness to pay for bagged organic peaches (i.e. peaches that have not received pesticides after bags were placed, about a month after bloom) allows the grower to cover costs (including labor) and sell at a higher price than non-bagged peaches; however, most large commercial peach growers in the southeastern U.S. do not have the workers needed to bag a large acreage as they mostly depend on H2A laborers, and they do not decide the number of H2A laborers needed just for one action (in this case, bagging) but for the entire crop season. On the contrary, we are seeing how small growers that run family-owned farms are much more open to adopt this strategy, as they can bag fruit based on local labor that is hired for specific periods of time. For the same reason, and also because of the consumer interest in this type of product seems to be greater at farmer markets, we foresee bagged peaches can preferentially reach local farmer-markets where growers can also get a better price for their produce. Major activities completed, data collection, and highlighted results: Research was conducted at the University of Florida, University of Georgia, and Clemson University. At the University of Florida, research was conducted by a doctoral candidate on-station, and on-farm for two projects investigating the effects of white paper bags with and without color inserts on peach fruit. Data collected included fruit quality, arthropod pest and pathogen injury, insect attraction, temperature/relative humidity inside the bag, and anthocyanin content. Laboratory analysis continued through July 2019. A manuscript covering results from the two-year on-farm experiment conducted on a USDA certified organic peach orchard has been prepared and will be submitted to HortScience in August 2020. A second manuscript on the colored bag study is nearly ready for committee review. Furthermore, the candidate successfully passed his oral Ph.D. qualification exam in February 2020 and was awarded one of six university-wide Graduate School Mentoring Awards in April 2020 for service mentoring undergraduate and high school students during his graduate education. The study at the University of Georgia compared consumer perception of bagged vs. unbagged organic peaches based on consumer panels. In addition, instrumental analyses were made between samples to characterize if major differences were present between samples. Compared to the control peaches, the bagged peaches were statistically smaller in size with less weight (although the difference in size did not reflect a change in grading category for the grower), a higher L* value for the lighter side of the skin, greater Kramer shear force required to slice, and a higher aroma liking score ($p \leq 0.05$). However, there were no differences in the total soluble solids, total titratable acidity, compression, puncture, and rest of the liking scores (appearance, flavor, sweetness, sourness, and texture). Majority of the consumers considered buying peaches from the nearby/local areas as important and considered appearance (absence of blemishes), firmness, and more aroma as the key characteristics for peaches, in general. Most of the consumers (69%) had not heard about \'bagged peaches.\' After being informed about definition, advantages, and disadvantages of bagged peach, \~63% of the consumers expressed positive attitude toward bagged peaches and \~60% indicated that they would become consumers of bagged peaches, and 47% were willing to pay more for them in the market. Bagged peaches have the potential to be competitive in the market provided that the consumers are made aware of enhanced quality of the fruits due to the bagging process. At Clemson University, this year we focused on two aspects: (1) consumer surveys and (2) composting of bags. Surveys were carried out with real customers at real farmers markets. A graduate student interviewed consumers at farmers markets in South Carolina, Georgia, and Florida. Data showed that more than 50% of consumers buy organically grown peaches sometimes and, while there were differences based on the demographics and location of the farmer\'s market, consumer would be willing to pay up to \$0.85 (average) extra per pound of peaches. Our cost-benefit analysis determined that a grower would cover costs if consumers pay

\$0.10 per pound more than the average cost of non-bagged peaches. Also, we have seen how removal and destruction of used bags may be a limitation for certain growers, as bags cannot be recycled at most local paper-recycling facilities. When consumers were asked about it, more than 90% of the consumers considered composting these bags instead of burning them or sending them to the landfill was important. Thus, a graduate student has started looking at composting them and this work is expected to provide valuable data within the next year. Key accomplishments: An eOrganic article on peach bagging titled \"How to use paper bags to protect organic peaches from insects and diseases in the southeastern United States\" has been published eXtension. The article was published on December 11, 2019, is open-access, and can be found at <https://eorganic.org/node/25727> (see citation 1) Preliminary findings on the colored bag experiment were presented by the doctoral candidate at the University of Florida in a poster at the 2019 ASA, CSSA and SSSA International Annual Meeting in San Antonio, TX on 12 November 2019 (citation 2). This graduate student also presented final results for the bagging experiment in an oral presentation at the 2020 Southern Region American Society of Horticultural Sciences in Louisville, KY on 1 February 2020, and was awarded first place in the Warren S. Barham Ph.D. Graduate Student Paper Competition (citation 3). A three-minute student presentation and entry in the graduate student Scholars Ignite competition (citation 4) was presented virtually at the American Society of Horticultural Science Annual Conference in August 2020.The graduate student at the University of Florida also presented final results of the colored bagging experiment (citation 5) virtually at this conference. A Clemson University graduate student presented results of the consumer preference studies at the Organic Agriculture Research Forum 2020 (organized by the Organic Farming Research Foundation; citation 6), and the Southern Sustainable Agriculture Working Group Conference (citation 7), held in Arkansas in January 2020. This student also gave a presentation on the use of paper bags by a growing sector of the population with an interest in growing peaches organically: backyard growers (citation 8) **PUBLICATIONS (not previously reported):** 2019/09 TO 2020/08 1. Type: Journal Articles Status: Accepted Year Published: 2019 Citation: Campbell, D., Treadwell, D., Melgar, J.C. and Chavez, D. 2019. How to use paper bags to protect organic peaches from insects and diseases in the Southeastern United States. eOrganic https://eorganic.org/node/25727 2. Type: Conference Papers and Presentations Status: Accepted Year Published: 2019 Citation: Campbell, D., Sarkhosh, A., Brecht, J., Gillett-Kaufman, J. and Treadwell, D. 2019. Effects of altered light transmission environments on quality and anthocyanin content of bagged peaches. ASA, CSSA, and SSSA International Annual Meeting. Nov. 8-11. San Antonio TX. Poster #1311 https://scisoc.confex.com/scisoc/2019am/meetingapp.cgi/Paper/118459 3. Type: Conference Papers and Presentations Status: Accepted Year Published: 2020 Citation: Campbell, D., Gillett-Kaufman, J., Sarkhosh, A., Brecht, J. and Treadwell, D. 2020. Efficacy of bagging as an alternative insect and disease management tool for peach (Prunus persica L.) in Florida. Oral presentation. Southern Region American Society for Horticultural Sciences Annual Conference. Louisville, KY. Jan. 30- Feb. 2, 2020 http://srashs.org/MeetingPrograms/2020%20Louisville/Program%202020%20200109%20F inal.pdf 4. Type: Conference Papers and Presentations Status: Accepted Year Published: 2020 Citation: Campbell, D., Sarkhosh, A., Brecht, J., Gillett-Kaufman, J., Liburd, O. and Treadwell, D. 2020. Improving organic peach fruit quality in Florida. American Society for Horticultural Sciences Annual Conference, Aug. 10-13, 2020. Virtual presentation. HortScience. 55(9) Sxxx-Sxxx (page number not available at the time of writing this report) 5. Type: Conference Papers and Presentations Status: Accepted Year Published: 2020 Citation: Campbell, D., A. Sarkhosh, J. Brecht, J. Gillett-Kaufman, O. Liburd and D. Treadwell. Effects of altered light transmission environments on microclimate, nutrient composition, and quality of bagged peaches. American Soc. Horticultural Sciences Annual Meeting, Aug 10-13, 2020. Virtual. HortScience. 55(9) Sxxx-Sxxx (page number not available at the time of writing this report) 6. Type: Conference Papers and Presentations Status: Accepted Year Published: 2020 Citation: Kule, A.K., Melgar, J.C., Vincent, E. and Chavez, D. 2020. Consumer perspectives on fruit bagging: a small grower horticultural practice for southern organic tree orchards. Oral presentation. Organic Agriculture Research Forum 2020. Little Rock, AK. January 23, 2020. 7. Type: Conference Papers and Presentations Status: Accepted Year Published: 2020 Citation: Kule, A.K., Melgar, J.C., Vincent, E. and Chavez, D. 2020. Consumer perspectives on fruit bagging: a small grower horticultural practice for southern organic tree orchards. Poster. Southern Sustainable Agriculture Working Group. Little Rock, AK. January 23-26, 2020. 8. Type: Conference Papers and Presentations Status: Accepted Year Published: 2020 Citation: Kule, A.K. and Melgar, J.C. 2020. Using paper bags for growing peaches in backyard gardens: a new horticultural practice in the United States. Poster. Southern Region &#65533; American Society for Horticultural Science Annual Conference. Louisville, KY. Jan. 30-Feb. 2, 2020.

2016/09 TO 2017/08 What was accomplished under these goals? Because of the devastating freeze we had in mid March of 2017in the Southeastern U.S. that caused peach crop losses of about 90% of the total production, most of the activities planned were not able to becarried out. Basically, we were not able to bag fruit for research because there was not fruit in the field.However, some data have been taken as part of the first objective, including data on temperature and relative humidity conditions inside bags versus outside bags. This data are key to understand the conditions where diseases thrive and why bagging has an impact under our

climate.Furthermore, efforts regarding dissemination of this strategy to growers and the general public have been done (objective 3). We think this is important because growers will not be able to sell this product at a premium if the public is not well informed about what a bagged peach is and how they have been produced.
PUBLICATIONS (not previously reported): 2016/09 TO 2017/08 No publications reported this period.

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Organic Confluences Conference: Making Research Count

Accession No.	1010335
Project No.	VT.W-2016-04418
Agency	NIFA VT.W\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2016-51300-25730
Proposal No.	2016-04418
Start Date	01 SEP 2016
Term Date	31 AUG 2017
Grant Amount	$50,000
Grant Year	2016
Investigator(s)	Shade, J.
Performing Institution	ORGANIC CENTER FOR EDUCATION AND PROMOTION, 28 VERNON ST STE 413, BRATTLEBORO, VERMONT 05301

NON-TECHNICAL SUMMARY

The primary goal of this conference is to bring together a diverse group of organic stakeholders toimprove the dissemination and adoption of scientific research aimed at overcoming commonchallenges to organic production. The conference will accomplish this goal by addressing potentialcommunication pitfalls while providing a venue for scientists, farmers, policymakers and organicstakeholders to assess the state of research communication and barriers that constrain diversestakeholders from utilizing research results and adopting new technologies. Sessions will includeworkshops on focused case studies to evaluate research and communication on specific agronomictopics as well as discussions and panels to assess (1) attributes that make research useful to farmers,(2) how to improve stakeholder involvement in the development of research priorities, (3) how toincrease communication among scientists and policymakers, (4) extension and resource availabilityand (5) the merits and shortfalls of current organic agriculture research funding. The conferencewill culminate with discussions to synthesize information presented at the conference andrecommendations will be developed for improving communication among groups. Participants willinclude farmers, scientists, industry members, and key policy makers. The conference will be heldin Washington, D.C. during the spring of 2017, in conjunction with the Organic Trade Association\'sPolicy Conference and Farmer\'s Advisory Council Summit, which are attended by organic farmersfrom small and large farms, distributors, researchers, leading and emerging organic brands, retailersand policymakers. Proceedings will be made available through The Organic Center and published by eOrganic.

OBJECTIVES

The primary goal of this conference is to address constraints in organic production including barriers to increasing adoption of organic practices and expanding organic acreage. In an effort to achieve this broader goal we will bring together a diverse group of organic stakeholders to improve the dissemination and adoption of scientific research aimed at overcoming common challenges to organic production. While scientists are increasingly conducting research and developing new methods to address the diversity of obstacles faced by organic farmers, research results are often slow to reach growers, and farmers can be hesitant to adopt new methods and technologies. The need for improved research dissemination and utilization also extends to policymakers. Agricultural issues are debated by legislators and translated into policy by executive agencies. Scientific data are

needed at every step to develop meaningful regulations, yet communication among scientists and policymakers is lacking. As a result, policymakers may not have access to existing information, and scientists may not be aware of knowledge gaps that need to be filled.Barriers to the dissemination and adoption of scientific research results are likely occurring on a number of levels.Due to a lack of clear communication channels, researchers may not be fully aware of priorities relevant to organic and transitioning farmers or policymakers, and research results may not be translated into actionable recommendations: Clear lines of communication among scientists, farmers and policymakers are necessary to ensure that existing solutions and tools are reaching their target audiences, and to ensure that researchers are aware of challenges that require research and innovation. Furthermore, if pertinent research is completed but the results are not presented in a manner that is accessible to non-scientists, relevant information may remain underutilized by farmers and policymakers.Researchers may not be disseminating research results through the best channels to reach organic farmers or policymakers: New funding initiatives for organic agriculture research, such as the OREI, are expected to encourage researchers that have traditionally focused on conventional farming systems to enter the realm of organic agriculture research. While this shift is generally positive, research suggests that conventional and organic growers are likely to utilize different resources to obtain information. Additionally, policymakers are often not included as target audiences for research dissemination. Accordingly, it is imperative that researchers are not simply incorporating outreach and education plans into their research programs but that they are disseminating research through appropriate outlets to ensure that results reach those whom they were intended to benefit.Existing outlets for research dissemination are not sufficient to meet the needs of organic farmers: Many educators, cooperative extension agents and USDA personnel who do not work with organic producers regularly lack a basic understanding of organic agricultural practices, the needs of organic and sustainable farmers, or existing research aimed at addressing those needs. Furthermore, existing resources for organic and sustainable farmers are scarce across many parts of the country. For instance, the National Resource Conservation Service (NRCS) funds only one organic specialist for the entire U.S. Organic agriculture research funding programs may not consistently prioritize research most needed by organic producers: Organic producers must understand and rely on complex biological processes that occur over long time periods. Even when scientific interests and producer needs are in sync, the majority of research funding is restricted to short-term experiments using reductionist approaches. While these strategies are common in conventional agriculture research, they may not be ideal for sustainable and organic systems, which require more holistic methodology. Similarly, because organic farming relies on an understanding of biological processes that vary based on localized factors including topography, soil chemistry and climate, research results from one area or crop may not translate to others.The Organic Confluences Conference will address each of these potential communication pitfalls through panels, case studies and discussions, while providing a venue for scientists, farmers, policymakers and organic stakeholders to assess the state of research communication and barriers that constrain diverse stakeholders from utilizing research results and adopting new technologies.Conference participants will include organic and transitioning farmers, scientists, extension agents, industry members and key policy influencers. The conference will be held in Washington, D.C., on May 2-3, 2017, in conjunction with the Organic Trade Association\'s Policy Conference and Farmer\'s Advisory Council Summit, which are attended by organic farmers from small and large farms, distributors, researchers, leading and emerging organic brands, retailers and policymakers.

PROGRESS

2016/09 TO 2018/08 Target Audience:The target audiences reached by our efforts during this reporting period includedorganic agriculture researchers, industry members, organicfarmers, retailers, policy makers and other organic stakeholders. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest?The report has been disseminated and publicized via the eOrganic website and newsletter, the Organic Center\'s website and newsletter and the Organic Trade Association\'s website and newsletter. The report was shared with all conference participants and was shared via email with almost 8,000 U.S. certified organic farmers. The report was also shared with program leaders at USDA-NIFA. Additional outreach and dissemination was targeted at land grant universities with organic and sustainable agriculture programs. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

IMPACT

2016/09 TO 2018/08 What was accomplished under these goals? During this reporting period The Organic Center wrote, published and disseminated a white paper developed from the conference entitled \"Making Organic Research Count: Outcomes from the 2017 Organic Confluences Summit\". This report is based on presentations and discussions that took place at the conference. It covers four case studies that were presented

at the meeting, discusses challenges to the effective design, implementation and dissemination of organic agriculture research, and provides recommendations to increase both the significance and reach of results. The main challenges identified included improving communication among all stakeholders, addressing inadequate engagement of underreppresented groups, ensuring that research design is relevant to the needs of end-users, making research accssible, and improving access to research funding. Addressing these challenges will ensure that organic agriculture research contributes to the success and growth of organic agriculture in the U.S. The report has been disseminated and publicized via the eOrganic website and newsletter, the Organic Center\'s website and newsletter and the Organic Trade Association\'s website and newsletter. The report was shared with all conference participants and was shared via email with almost 8,000 U.S. certified organic farmers. The report was also shared with project leaders at USDA-NIFA. Additional outreach and dissemination was targeted at land grant universities with organic and sustainable agriculture programs. **PUBLICATIONS (not previously reported):** 2016/09 TO 2018/08 Type: Other Status: Published Year Published: 2018 Citation: Misiewicz, T. and Shade, J. 2018. Making Organic Research Count: Outcomes from the 2017 Organic Confluences Conference. The Organic Center, Washington D.C. Available at https://www.organic-center.org/wp-content/uploads/2018/02/The-Organic-Center-2017-ConfluencesWhitePaper.pdf

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Strategies to Prevent and Mitigate Ap of Gmo?s in Organic and Export Alfalfa Hay

Accession No.	1010487
Project No.	WNP07691
Agency	NIFA WN.P\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2016-51300-25739
Proposal No.	2016-04485
Start Date	01 SEP 2016
Term Date	31 AUG 2017
Grant Amount	$49,915
Grant Year	2016
Investigator(s)	Fransen, S.
Performing Institution	WASHINGTON STATE UNIVERSITY, 240 FRENCH ADMINISTRATION BLDG, PULLMAN, WASHINGTON 99164-0001

NON-TECHNICAL SUMMARY

This organic focused alfalfa conference is designed to address key issues relating to adventitious presence (AP) of the glyphosate resistant (GR) genes in GMO alfalfa. Producers are concerned about seed and forage contamination impacting their organic and conventional alfalfa fields and markets. The program agenda is packed with expert presenters reviewing current alfalfa production strategies, latest organic alfalfa research results, and management and mitigation strategies specific to the PNW region. Additionally, we have included presenters from the impacted industries, e.g., hay production, organic dairy and livestock. Collectively, invited presenters bring many skills and interests, knowledge and experiences speaking on topics such as alfalfa gene flow, identifying AP-free seed sources, testing for AP in seed and hay, mitigation strategies and direct impacts in both domestic and international markets. We have invited Beth Nelson from the National Alfalfa and Forage Alliance to present at our luncheon. She is recognized as one of the major supporters of the alfalfa industry and brings a wide array of knowledge and experiences at the national level to share with conference attendees. We have designed this single day conference for significant networking and transfer of information. The panel encourages direct audience participation and discussion. Such a conference will ensure alfalfa hay and seed production for organic, GMO-sensitive and non-sensitive markets can continue to prosper in the United States. The issue of AP will not disappear after this conference but we hope to stimulate open dialog and discussions along all participants based on good science and future thinking. We hope to build the foundation for future, self-funded, spin off conferences from this funded project.

OBJECTIVES

Legislatively Defined Goals and Percentage Effort from proposed Conference.Our conference aligns perfectly with OREI legislative goals: 1, 35%, facilitate improvement of organic production and processing, by presenting new information on gene flow between two hay fields, from seed to hay fields, from feral plants to hay fields, from feral plants to seed fields, from hay to seed fields and from seed field to seed field; 3, 10%, international trade markets, by discussing alfalfa exports to China that were stopped due to AP in western hay; 4, 25%, desirable traits for organic commodities, by dairy and livestock producers sharing their required traits from alfalfa, and presenting field results from organic nutrient treatments applied to alfalfa hay for yields and quality; 5, 20%,

marketing constraints to expand organic products, by dairy and livestock producers who\'s business is to produce organic milk and livestock products, along with economic evaluation of marketing organic hay both domestically and internationally; and 7, 10%, examine environmental interactions impacting organic products, by assessing gene flow through various avenues that directly alter alfalfa seed or through feral plants scattered throughout the environment. Project Methods A planned educational regional conference is planned for January 17, 2017 at the Three Rivers Convention Center at Kennewick, WA. This jam-packed single day event is designed to not only provide current and relevant science based information to attendees but to have grower / producer perspectives presented highlighting the constraints and issues they face when growing or utilizing organic alfalfa hay in both organic and traditional commercial farming operations in the Pacific Northwest. Washington State University ARC will be subcontracting with Ag Association Management Northwest for services to assist in various aspects of this conference. They have a long history of managing the Northwest Hay Expo and Trade Show and are ideal to host the online registration site and other non-technical details of the conference.The developed but not confirmed conference agenda and specialist presenters and panel is highlighted in the Products tab. Each person in the developed conference agenda, who previously committed to this project, will be confirmed within the next few weeks. Each will be asked to provide not only a written document of their remarks, along with PowerPoint slides but also a short CV and contact information so attendees can follow up with post-conference questions as needed. We expect a prolonged post-conference dialog, as judged by comments and survey of attendees, if so we will establish a discussion tab to continue. This will also be an active site where planning for future self-funded conferences can be developed.The conference is designed to meet many of the stakeholder needs, which are many and very diverse. We cannot hope to provide information and address each one in this one-day conference but if we are truly successful this OREI funded conference will set the stage, acting as a catalyst for biennial regional issue based conferences formatted similarly to this one.A pre and post evaluation will be conducted measuring knowledge gained, changes in attitudes and planned actions by the attendees. These data will be collected and shared with OREI, the three state hay organizations, and team members. **FINAL REPORT** 09/01/16 to 08/31/17 Outputs Target Audience:The AP of GMO's in organic and export alfalfa hay regional conference primary target audience are stakeholders and organic alfalfa growers, conventional alfalfa hay growers, dairy and livestock producers from Washington, Oregon and Idaho, the PNW. The secondary audience is USDA-NRCS and FSA officers, Conservation District advisors, Extension agents and specialists, crop consultants, seed suppliers and growers, and the popular press. The goal is to provide each participant with a USB drive with published relevant papers, copies of Powerpoint presentations and additional key resource materials to increase their understanding of the nature and risk of gene flow in alfalfa and effective ways to minimize them. This conference is of interest to researchers working with alfalfa and to all stakeholders and growers who are interested in growing and certifying organic alfalfa, and producing conventional alfalfa bound for AP sensitive markets. Stakeholders and organic growers need research based and unbiased recommendations with best management strategies to facilitate meeting organic and non-GMO hay requirements. Understanding of gene flow and associated risks between GMO and organic alfalfa is an essential component and will allow organic growers to set sustainable, realistic, and cost-effective goals. This conference is designed to meet stakeholder needs, which are multiple and diverse. We cannot hope to provide information and address each need in this one-day conference but if we are truly successful this OREI funded conference will set the stage, acting as a catalyst for biennial regional issue based conferences formatted similarly to this one. Changes/Problems:We also experienced record breaking cold temperatures and snowfall before the conference, and actually all winter, see appendix newspaper articles from the local TriCity Herald paper. The project team recognizes that some of the producers who had registered and didn't attend was because of the weather conditions and snowfall they had to contend with. What opportunities for training and professional development has the project provided?Training and PDP? None but many of the agriculture producers have contacted one or more of the team members requesting another conference follow up. They had learned more than expected from our January 2017 conference and recommended follow up conferences in other areas of the PNW region. How have the results been disseminated to communities of interest?Dissemination of results? We have not distributed these results at this time. Our team will be writing an article for Progressive Forage Grower highlighting what happened and the importance of communication and further understanding of these issues. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? What was accomplished? We planned and conducted a very comprehensive conference addressing the current topic and concern among many alfalfa and forage producers in the Pacific Northwest, that of adventitious presence in and contamination of organic and non-transgenetic alfalfa seed for domestic and foreign export markets. The response from those attending was tremendously supportive in that 89% felt they knew much more about the issues than before the conference. Test questions we asked and answers are as follows: Question 1. Broiler chcken manure has higher nitrogen content than beef feedlot manure by an appoximate factor of: a) half as much - answer 8%; b) equal \-- 8%; c) 1.5 times \-- 11%; d) 2.0 times 62% (correct answer); e) 3.0 times \-- 11%. Question 2. Broiler chicken manure has higher phosphor content than beef feedlot manure by an approximate factor of: a) half as much \-- 11%; b) equal \-- equal \-- 29%; c) 2.0 times \--

44% (correct answer); d) 3.0 times \-- 8%; e) 4.0 times \-- 8%. Question 3. Broiler chicken manure has higher potassium content than beef feedlot manure by an approximate factor of: a) half as much \-- 12%; b) equal to \-- 30%; c) 1.35 times 23% (correct answer); d) 1.75 times \-- 12%; e) 2.0 times \-- 23%. Question 4. The yield gap from organic alfalfa hay to conventional alfalfa hay is: a) 0.5 \-- 4%; b) 0.25 \-- 4%; c) 0.15 \-- 29%; d) 0.02 \-- 55% (correct answer), e) equal to \-- 8%. Question 5. In the last 25 years Idaho certified organic alfalfa hay acreage has: a) half as much \-- 0%; b) equal to \-- 4%; c) 50% more \-- 8%; d) 100% more 40% (correct answer); e) 200% more \-- 48%. Question 6. Since propronic acid is technically an organic acid, is it legal in all states to apply to certified organic hay? a) true \-- 11%; b) false \-- 89% (correct answer). Question 7. A certified organic alfalfa grower is not required to control noxious weeds since most synthetic herbicides are not registered for organic use? a) true \-- 22%; b) false \-- 78% (correct answer). Question 8. Which region has the largest for organic sales? a) West Coast US \-- 89% (correct answer); b) SW US \-- 4%; c) East Coast US \-- 7%; d) Northeast US \-- 0%. Question 9. Which Northest state has the largest organic milk production: a) Washington \-- 21%; b) Idaho \-- 6%; c) Oregon \-- 72% (correct answer); d) Alaska 0%. Question 10. What is the differnce in milk production per cow between conventional and organic productioin? a) Organic + 15% \-- 4%; b) equal \-- 11%; c) Organic - 15% \-- 85% (correct answer). Question 11. Primary pollinators used in Wahington alfalfa seed prodcution: a) honey bees \-- 0%; b) alkali bees \-- 0%; c) leaf cutter bees \-- 7%; d) b and c \-- 72% (correct answer); e) all the above \-- 21%. Question 12. Gene flow in alfalfa only occurs due to pollinators: a) true \-- 23%; b) false \-- 77% (correct answer). Question 13. Applicaiton of glyphosate kills all feral plants: a) true \-- 7%; b) false \-- 93% (correct answer). Question 14. Did this conference increase your knowledge of gene flow? a) yes \-- 89%; b) no \-- 11%. Question 15. How amny organic acres do you farm? a) 0 \-- 84%; b) 1-100 \-- 4%; c) 101-250 \-- 4%; d) 250-500 \-- 0%; e) 500 - 1000 \-- 4%; f) 1000 - 2000 \-- 0%; g) 2000 - 3000 \-- 0%; h) > 3000 \-- 4%. Question 16. How many non-organic alfalfa acres do you farm? a) 0 \-- 46%; b)1-100 \-- 19%; c) 101 - 250 \-- 8%; d) 250 - 500 \-- 4%; e) 500 - 1000 \-- 8%; f) 1000 - 2000 \-- 11%; g) 2000 - 3000 \-- 0%; h) >3000 \-- 4%.

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Breeding and Agronomy of Quinoa for Organic Farming Systems

Accession No.	1010611
Project No.	WNP03110
Agency	NIFA WN.P\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2016-51300-25808
Proposal No.	2016-04408
Start Date	01 SEP 2016
Term Date	31 AUG 2020
Grant Amount	$1,999,950
Grant Year	2016
Investigator(s)	Murphy, K.
Performing Institution	WASHINGTON STATE UNIVERSITY, 240 FRENCH ADMINISTRATION BLDG, PULLMAN, WASHINGTON 99164-0001

NON-TECHNICAL SUMMARY

Quinoa is a nutritious and broadly adapted seed crop in high demand in the U.S. and around the world. However, information regarding the optimal varieties, best management practices, and marketing options for quinoa across diverse regions in the U.S. is lacking. To further develop the domestic organic quinoa market, stakeholders have identified several high priority research needs, including (1) breeding of quinoa varieties with heat tolerance; (2) breeding of quinoa varieties with insect and pathogen resistance; and (3) the development of agronomic systems and tools that promote weed control. Our project addresses these stakeholder needs by developing new quinoa varieties and best management practices for growing organic quinoa across multiple regions in the U.S. Our long-term goal is to develop a vibrant and strong organic quinoa supply chain across the U.S., which would allow organic farms to diversify their operations and increase their profitability by incorporating quinoa. This project will provide urgently needed information regarding organic quinoa production as an alternative crop. Our research and extension objectives are designed to create economic and ecological opportunities for quinoa production across a diversity of regions in the U.S. The rationale underlying the proposed research is that U.S. growers will have new technology and information for growing organic quinoa successfully and profitably. The results of the project will contribute the facilitation of organic agricultural production by generating research information, and educating clientele on a range of topics related to quinoa production and marketing. We expect our project to increase the number of organic quinoa growers in suitable growing regions across the U.S. Additionally, we expect to provide a sound on-farm research-based platform for existing farmers and emerging quinoa growers to diversify their current cropping rotations and marketing options.Critical needs of quinoa distributors, wholesalers, and retailers focus on the need for reliable sources of domestic, organic, high-quality quinoa. Imports of quinoa have increased from 4 million pounds in 2007 to over 93 million pounds in 2015 (Nunez de Arco, personal communication). Evaluating the potential for quinoa production across diverse regions in the U.S. is important to consumers and distributors and could prove profitable for domestic farmers. Identification of varieties with specific and consistent quality traits across variable environments is critical to the successful establishment of a domestic quinoa market. Approximately 65 to 70% of annual U.S. imports of quinoa is organic (Nunez de Arco, personal communication), and the development of a strong, resilient organic and domestically grown quinoa supply is necessary to fill this need.In the U.S., quinoa is a relatively new crop to the farmer and a relatively new food to the consumer, thus we must improve our knowledge of quinoa market potential and supply-chain challenges. This research will determine the economicsof crop enterprises, including that of quinoa, in organic grain production systems. Economic findings will provide valuable information for growers in designing their own

cropping systems. For example, our financial analyses will provide immediately useful information to growers about how their management practices related to pests and soil quality impact the economic returns of their operations and steps that can be used to reduce their costs and improve sustainability.Farmers seeking to diversify their production systems and marketing options, and U.S. distributors currently experiencing severe supply shortages of quinoa, stand to benefit significantly from this research. Potential economic metrics will be measured through documented changes in quinoa growing acreage in the target regions, and in the ability of quinoa distributors to meet the growing consumer demand by sourcing and supplying domestically grown, organic quinoa. Evaluation of program impact will occur through discussions with the advisory panel and by a mail survey of current and potential organic quinoa growers in WA, UT, MN, and MD in years 1 and 4 of the project. Questions will probe production practices, economics, perceptions of opportunities and constraints, and future research and Extension needs.Farmers and quinoa distributors have been instrumental in the development of this project. To identify and prioritize critical research and extension objectives for this project, we gathered input from farmers and other stakeholders through numerous field days, demonstrations and roundtables. Moreover, our preliminary variety trials have all been conducted in farmers\' fields across various regions of the U.S. One trial in Beltsville, MD, for example, is located on the Firebird Research Farm, which is part of University of District of Columbia (UDC). The UDC is a historically black serving college (HBSC) that has the unique position of being the only urban 1860s land grant university in the U.S. The farm holds numerous field days throughout the year attended by urban/suburban residents of the region, and between the Firebird Farm and the urban agriculture activities around the campus in DC, the university conducts agricultural outreach for over 30,000 people a year. A Stakeholder Advisory Committee, of which Firebird Farm is represented, was formed for this current proposed project in the winter/spring of 2016, consisting of representative growers, processors, wholesalers, retailers, and end-users.We will use a broad array of extension and outreach tools to reach a range of stakeholders. These include multiple field days across all target regions of this project, several webinars, Extension bulletins, workshops, participatory research with farmers, yearly reports on our proposed project website, talks and posters at farmer and academic conferences, and papers in peer-reviewed journals. The goals of the Communication/Outreach Plan are to: (1) increase awareness of challenges andopportunities for production of organic quinoa, and (2) disseminate information generated in research and demonstration trials to growers and processors.

OBJECTIVES

The long-term goals of this multi-region, integrative project are to: (1) breed high-yielding, nutritious quinoa varieties for organic systems that are adapted to abiotic and biotic stresses through (a) the Washington State University (WSU) quinoa breeding program and (b) a cohesive variety testing program in Washington, Utah, Minnesota, and Maryland; (2) evaluate and develop best management practices to optimize organic quinoa production systems across diverse environments; (3) understand the economics of domestic organic quinoa production, processing and marketing, and; (4) disseminate information to target diverse audiences using a range of extension tools.Research and Extension Objectives1. Evaluate and select quinoa varieties and breeding lines in organic systems for critical traits of interest;2. Develop best management practices for organic quinoa production in diverse environments in the U.S.;3. Characterize diverse quinoa genotypes for beneficial mycorrhizal, rhizosphere and endophytic associations;4. Evaluate processing and end-use quality traits and nutritional value of quinoa varieties and breeding lines;5. Measure the economic performance of different organic quinoa and grain production systems; and6. Disseminate information about, and develop farmer/distributor relationships for, organic quinoa production and marketing.

APPROACH

Objective 1. Evaluate and select quinoa varieties and breeding lines in organic systems for critical traits of interest. Four experiments will be conducted to help achieve the overall goals of Objective 1: (1) multi-region, certified organic quinoa variety trials; (2) quinoa breeding, selection and varietal release within, and for, organic systems; (3) genetic characterization of quinoa germplasm and genome wide association study (GWAS) of genes controlling mildew resistance; and (4) heat-stress physiology and screening tools for variety selection. Objective 2. Develop best management practices for organic quinoa production across diverse environments in the U.S. Each region in this project presents distinct agronomic challenges, including considerable differences in precipitation; soil type, fertility and biology; dominant cropping systems; environmental stresses; landscape; and climate. The agronomic trials in this objective have been tailored to evaluate quinoa production in each environment. Objective 3. Evaluate diverse quinoa genotypes for beneficial mycorrhizal, rhizosphere and endophytic associations. Organic farming systems rely largely on microbial-mediated processes for nutrient availability. AMF play an important role in plant uptake of nutrients, especially with the ability to incorporate

organic forms of P (Kahiluoto and Vestberg 1998) and N (Hawking et al. 2000), and therefore are particularly important for low-input and organic systems that cannot rely on calculated inputs of synthetic nutrients. Quinoa belongs to a family of plants that has long been thought of as non-mycorrhizal, but there is growing evidence that quinoa can and does in fact form associations with AMF. Objective 4. Evaluate processing and end-use quality traits and nutritional value of quinoa varieties and breeding lines. Dr. Ganjyal of WSU will coordinate this component of the project. This will include evaluation of all the varieties and breeding lines for their nutritional value (including mineral concentrations, amino acid profiles, fiber content, bioactive compounds), processing properties (including thermal and pasting properties) and capacity to fit into selected model food systems (including noodle, cereal and snack products). Objective 5. Measure the economic performance of different organic quinoa and grain production systems. In the past two decades, due to increased demand in the U.S. and Europe, the price of quinoa has increased dramatically from \$892/ton in 1999 to \$2,500/ton in 2011. The price of organic quinoa is even higher, averaging \$3,100/ton. Amazingly, prices tripled from 2011 to 2013, reaching \$7,500/ton. In the U.S. alone, imports of quinoa rose from 7 million pounds per year in 2007 to the current rate of over 95 million pounds per year. In the U.S., quinoa is a relatively new crop to the farmer and a relatively new food to the consumer, thus we must improve our knowledge of quinoa market potential and supply-chain challenges. This research will determine the economicsof crop enterprises, including that of quinoa, in organic grain production systems. Economic findings will provide valuable information for growers in designing their own cropping systems. For example, our financial analyses will provide immediately useful information to growers about how their management practices related to pests and soil quality impact the economic returns of their operations and steps that can be used to reduce their costs and improve sustainability.Objective 6. Disseminate information about, and develop farmer/distributor relationships for, organic quinoa production and marketing.Dr. Creech of USU will lead the Extension Agronomy component of this project. Dr. Ganjyal of WSU will lead the post-harvest, end-use quality, processing and new product development components of this project. Our model for reaching agricultural producers and professionals is based on: (1) using University Research and Extension Centers as testing sites to screen quinoa varieties; (2) evaluating the most promising lines and production practices in on-farm trials using statistically robust trial designs; (3) using research trials (on and off research centers) as centers of dissemination; and (4) developing outreach materials and disseminating information through a variety of printed and digital media. **FINAL REPORT** 09/01/16 to 08/31/21 **Outputs** Target Audience:We targeted small-, mid-, and large-scale growers, backyard gardners, chefs, consumers, bakers, millers, processors, researchers, scientists, and the general public. Each of these audience groups was reached through a series of publications in peer reviewed academic journals, one book chapter, and presentations at academic conferences, farmer meetings, and other venues. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? We conducted an On-Farm Quinoa Selection Workshop: Here we work with farmers in western Washington to conduct both positive and negative selection of multiple diverse populations. As a multi-year endeavor, we are able to show population improvement over time, as well as grow over 200 individual farmer selections in multiple organic locations. These selections are among the advanced genotypes that will most likely be released as varieties in the near future. We conducted multiple field days and food processing and product development workshops to train food company employees in different ways to prepare quinoa and develop quinoa products. During COVID, due to restrictions in travel, we were limited in training and professional development opportunities for team members. However, our team was able to provide a field and post-harvest phenotyping training workshop and a participatory breeding workshop at the quinoa symposium for interested participants. In addition, many of the participants utilized the quinoa symposium as a professional development opportunity, and we provided over 200 certificates to attendees. How have the results been disseminated to communities of interest?Throughout the project, we focused much of our efforts on disseminating the results and knowledge gained from our research to multiple stakeholders and communities of interest. We published 2 peer-reviewed Extension bulletins, including "Growing quinoa in Washington State" and "Growing quinoa in home gardens". We delivered over 30 presentations throughout the grant at multiple venues, including Cascadia Grains annual conferences, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America annual conferences, and many others. We focused on reaching organic (and conventional) farmers, food companies and quinoa industry representatives, general consumers interested in quinoa, chefs, and academics, among others. We held annual field days in multiple locations and conducted workshops directed at quinoa farmers and food companies interested in quinoa. Since 2020, due to COVID-19, we were not able to conduct field days and face to face workshops and presentations as we do during a normal year. Yet, this was our most successful year in terms of dissemination of our years of results of organic quinoa breeding, agronomy, ancestral knowledge, genetic resources, anthropology, sociology, physiology, high-throughput phenotyping, genomics, nutrition and food science. In August 17-19, 2020, Washington State University hosted the 2nd International Quinoa Research Symposium, an online, bilingual event. The symposium was offered free of charge so any interested individuals could attend regardless of economic circumstances. We reached well over 1000 stakeholders through 51 invited speakers plus 35 poster participants, all of whose presentations were delivered in english and spanish. The

presentations were all prerecorded, and all the speakers were available after their talks for live question and answer sessions and networking. To encourage networking, we had 296 participants in the online networking platform Slack, with 3250 messages sent between members throughout the event. There were 6021 collective YouTube views of all Symposium material on the Sustainable Seed Systems Lab channel including 1072 views of Day 1 of the Live Symposium. Each of the 50+ presentations were recorded and are available on our Sustainable Seed Systems Lab YouTube channel. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? Evaluate and select quinoa varieties and breeding lines in organic systems for critical traits of interest. Throughout this project, organic quinoa variety trials were carried out in mulitple locations in Washington, Maryland, Minnesota, Utah and Montana. These varieties were analyzed for a suite of agronomic and post-harvest nutritional and end-use quality traits. These data will assist us in determining which breeding lines we will release as new quinoa varieties in the near future. Most of these characteristics did not have standard phenotyping protocols in place, and so our group worked closely with other scientists conducting quinoa research worldwide, and developed and published a paper in 2021 in the journal Plants titled: "Quinoa phenotyping methodologies: An international consensus". This research has had immediate impact on how we measure and report traits in a uniform and consistent manner. In total we published 10 peer-reviewed papers that described the agronomic and post-harvest traits of diverse quinoa varieties during this project, ranging from yield, maturity, heat and drought tolerance to insect and pre-harvest sprouting resistance to protein and amino acid content, and multiple characteristics required by food and processing companies to develop new quinoa-based products. Develop best management practices for organic quinoa production in diverse environments in the U.S. We tested quinoa across multiple environments and were able to pinpoint some key latitudinal, elevation, rainfall/irrigation, and temperature requirements necessary for quinoa to thrive. In addition, we focused on multiple ways to grow quinoa ranging from direct seeding to transplanting, dryland vs. irrigation, and insertion into traditional cropping rotations. We worked closely with organic farmers in each target environment to devise ways to maximize weed competitiveness, yield, and seed quality. Key papers resulting from this work include "Sustainable intensification of quinoa in peri-urban environments in western Washington state utilizing transplant vs. direct-seed methods"; and "Productivity and soil quality of organic forage, quinoa, and grain cropping systems in the dryland Pacific Northwest, USA";. Characterize diverse quinoa genotypes for beneficial mycorrhizal, rhizosphere and endophytic associations. The USDA-ARS lab headed by Dr. Maul evaluated the plant rhizosphere, and endophytic microbe associations, seeking plant beneficial and protective functions. This team conducted three field trials collecting roots, stems, leaves and developing seed heads from select advanced lines provided by the WSU team. Endophytic and root associated microbes were isolated using combination of traditional microbiological and advanced metagenomic techniques. Culturable microbes and fungi were enriched using selective microbiological growth media and screened for the traits of phosphorous solubilization, nitrogen fixation (diazotrophic) and antibiotic production using gene targeted PCR, cloning and sequencing. Over 300 bacterial isolates were collected from the roots and stems of advanced quinoa lines. Analysis of phosphatase activity and increased/decreased availability of P in the root zone will be evaluated with bacterial strains that show the greatest root zone persistence in the greenhouse studies. Manuscript preparation is currently underway for this study. An additional study was carried out at WSU that evaluated 10 quinoa varieties across 8 mycorrhizal treatments. Results are published in a paper titled "A plant-fungus bioassay supports the classification of quinoa as inconsistently mycorrhizal" published in the journal Microbial Ecology. Evaluate processing and end-use quality traits and nutritional value of quinoa varieties and breeding lines. Throughout the project, we characterized hundreds of quinoa varieties for a wide variety of end-use quality and nutritional characteristics. This objective has resulted in substantial baseline information for quinoa grown in the U.S. that is critical for food processing and product formulations by the domestic quinoa food industry. Throughout this process we worked closely with food companies that process and/or sell organic quinoa in the U.S. Several papers have been published in leading journals such as Journal of Food Science (3x), Cereal Chemistry, Journal of Cereal Science, and Frontiers in Plant Science. Through this work we developed critical characteristics that will be important to evaluate and include in the upcoming newly released quinoa varieties (scheduled for 2022). All of our advanced breeding lines have been fully characterized and this information will be published in 2022. One key paper titled "Seed composition and amino acid profiles for quinoa grown in Washington State" published in Frontiers in Nutrition evaluated 100 quinoa genotypes grown across 4 organic farms for protein and essential amino acid content. This paper describes the urgency to select for nutritional value in quinoa breeding programs and the importance of understanding the roles of soil health and fertility in determining the amino acid profile. Quinoa is unique in that it can be a complete protein and our work will result in being able to provide farmers with fertility recommendations based on their soil type and variety to achieve optimal yield, and agronomic and nutritional outcomes. Measure the economic performance of different organic quinoa and grain production systems. We conducted a study that focused on integrating quinoa in 8 different 3-year sequences when rotated with key crops such as wheat, barley, and chickpeas. This study was published in the journal Agricultural Systems in a paper titled "Agronomic and economic performance of organic forage, quinoa, and grain crop rotations in the Palouse region of the Pacific Northwest, USA";. Our results show that

premiums for organic alfalfa and grains make these organic cropping systems economically viable for dryland production in the Pacific Northwest. Advances in organic weed control and regionally adapted quinoa varieties would further reduce the risk for farmers attempting this cropping system diversification. Disseminate information about, and develop farmer/distributor relationships for, organic quinoa production and marketing. Our team held multiple field days each year prior to the pandemic beginning in 2020. We published 3 peer-reviewed Extension articles on quinoa production, and delivered over 30 presentations and lectures on this project over the term of the grant. In addition, we reached well over 1000 stakeholders through the online bilingual 2nd International Quinoa Research Symposium. We had 51 speakers plus 35 poster participants, all of whose presentations were delivered in English and Spanish. The symposium was offered free of charge so any interested individuals could attend regardless of economic circumstances. Indigenous communities were among our target audience, and we brought in six invited indigenous speakers to speak about their current and generations-long work with quinoa. There were 6021 collective Youtube views of all Symposium material on the Sustainable Seed Systems Lab channel including 1072 views of Day 1 of the Live Symposium. We had 296 participants in the online networking platform Slack, with 3250 messages sent between members throughout the event. **Publications** - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Ganjyal, G. 2020. Quinoa End-use Quality and Processing. 2nd International Quinoa Research Symposium. August 16-19, 2020. - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Maughan, J. 2020. 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PROGRESS

2019/09 TO 2020/08 Target Audience:We targeted small-, mid-, and large-scale growers, backyard gardners, chefs, consumers, bakers, millers, processors, researchers, scientists, and the general public. Each of these audience groups was reached through a series publications in peer reviewed academic journals, one book chapter, and presentations at academic conferences, farmer meetings, and other venues. In addition, we reached well over 1000 stakeholders through the online bilingual 2nd International Quinoa Research Symposium. We had 51 speakers plus 35 poster participants, all of whose presentations were delivered in english and spanish. The symposium was offered free of charge so any interested individuals could attend regardless of economic circumstances. Indigenous communities were among our target audience, and we brought in six invited indigenous speakers to speak about their current and generations-long work with quinoa. There were 6021 collective Youtube views of all Symposium material on the Sustainable Seed Systems Lab channel including 1072 views of Day 1 of the Live Symposium. We had 296 participants in the online networking platform Slack, with 3250 messages sent between members throughout the event. Changes/Problems:COVID-19 required us to pivot from our plans of a face to face 2nd International Quinoa Symposium and host this event online. We feel this actually improved our outreach efforts and attendance numbers, as the symposium was both biliingual (Spanish and English) and free of charge. What opportunities for training and professional development has the project provided?Due to restrictions in travel, we were limited in training and professional development opportunities for team members. However, our team was able to provide a field and post-harvest phenotyping training workshop at the quinoa symposium for interested participants. In addition, many of the participants utilized the quinoa symposium as a professional development opportunity, and we provided over 200 certificates to attendees. How have the results been disseminated to communities of interest?Due to COVID-19, we were not able to conduct field days and face to face workshops and presentations as we do during a normal year. Yet, this

was our most successful year in terms of dissemination of our years of results of organic quinoa breeding, agronomy, ancestral knowledge, genetic resources, anthropology, sociology, physiology, high-throughput phenotyping, genomics, nutrition and food science. In August 17-19, 2020, Washington State University hosted the 2nd International Quinoa Research Symposium, an online, bilingual event. The symposium was offered free of charge so any interested individuals could attend regardless of economic circumstances. We reached well over 1000 stakeholders through 51 invited speakers plus 35 poster participants, all of whose presentations were delivered in english and spanish. The presentations were all prerecorded, and all the speakers were available after their talks for live question and answer sessions and networking. To encourage networking, we had 296 participants in the online networking platform Slack, with 3250 messages sent between members throughout the event. There were 6021 collective YouTube views of all Symposium material on the Sustainable Seed Systems Lab channel including 1072 views of Day 1 of the Live Symposium. These will be available to the public on our YouTube channel for years to come, and we anticipate many more views of all these relevant topics. During this reporting period we published six papers in peer-reviewed academic journals, and submitted three additional manuscripts for publication in peer-reviewed academic journals. Our lab groups have given multiple presentations, both poster and oral, at farmer meetings, departmental seminars and scientific conferences. These papers, manuscripts and presentations range across the following topics: quinoa breeding, physiology, high-throughput phenotyping, genetics, nutrition and food science. What do you plan to do during the next reporting period to accomplish the goals?During our last year of our project, for which we were granted a no-cost extension, we have the following objectives: a) Release the first WSU quinoa varieties developed in our breeding program. There will be an anticipated 3-5 new variety releases, and these will target different production environments and unique market classes of quinoa. b) Finalize and publish a genome wide association study (GWAS) on seed quality and nutritional traits of quinoa. c) Complete and publish two studies on soil ecology and microbial communities in field, greenhouse and lab studies. d) Finalize and publish our work with quinoa food science focusing on market class and product development. e) Publish a WSU Extension Bulletin quinoa production guide tentatively titled Growing Quinoa in Washington State. f) Finish writing and publish a review paper on the physiological mechanisms of seed dormancy and pre-harvest sprouting in quinoa. g) Complete research focused on understanding quinoa responses to vapor pressure deficit in three genotypes and two nutrient solutions. h) Continue growing our multi-location quinoa breeding trials and continuing our field phenotyping and nutritional phenotyping evaluations. i) Give presentations at grower and academic meetings, as well as at field days, either in person or virtual, as COVID circumstances allow.

2016/09 TO 2017/08 Target Audience:We targeted small-, mid-, and large-scale growers, backyard gardners, consumers, bakers, millers, processors, researchers, scientists, and the general public. Each of these audience groups was reached through a series of field days, publications in peer reviewed academic journals, an extension bulletin, and talks at academic conferences, farmer meetings, and other venues. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Farmer training: We conducted an On-Farm Quinoa Selection Workshop: Here we work with farmers in western Washington to conduct both positive and negative selection of multiple diverse populations. As a multi-year endeavor, we are able to show population improvement over time, as well as grow over 200 individual farmer selections in multiple environments. These selections are among the advanced genotypes that will most likely be released as varieties in the near future. How have the results been disseminated to communities of interest?Extension bulletin Oral presentations at conferences (academic, farmer-oriented, and end-user oriented) Poster presentations Field Days Workshops What do you plan to do during the next reporting period to accomplish the goals?We plan to conduct the second year trials of Objective 1 and 2 above, and begin research on Objectives 3 to 5. We intend to continue to carry out a robust dissemination program (Objective 6).

2017/09 TO 2018/08 Target Audience:We targeted small-, mid-, and large-scale growers, backyard gardners, chefs, consumers, bakers, millers, processors, researchers, scientists, and the general public. Each of these audience groups was reached through a series of field days, publications in peer reviewed academic journals, an extension bulletin, and talks at academic conferences, farmer meetings, and other venues. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest?During this reporting period we published six papers in peer-reviewed academic journals, one extension bulletin, and submitted six manuscripts for publication in peer-reviewed academic journals. Our lab groups have given multiple presentations, both poster and oral, at farmer meetings, departmental seminars and scientific conferences. These papers, manuscripts and presentations range across the following topics: quinoa breeding, physiology, high-throughput phenotyping, genetics, nutrition and food science. What do you plan to do during the next reporting period to accomplish the goals?We plan to conduct the thirdyear trials of Objective 1 and 2 above, and continue research on Objectives 3 to 5. We intend to continue to carry out a robust dissemination program (Objective 6).

IMPACT

2019/09 TO 2020/08 What was accomplished under these goals? In FY2020, organic quinoa variety trials were carried out in mulitple locations in Washington, Maryland, and Montana, and are currently being processed and analyzed for yield, seed size, seed color, mineral concentration and amino acid content. This information will assist us in determining which breeding lines we will release as the first WSU quinoa varieties in 2021. To further accelerate variety release, we sent our top 10 breeding lines to Chile over the winter of 2019-2020 for seed purification and increase. We are in the final stages of determining which varieties we will release; this decision will be based on agronomic traits, grain yield, post-harvest quality and nutritional characteristics of the top breeding lines. Through three recent food science studies completed in the last 12 months (manuscripts in prep), we were able to identify different market classes and end uses of our top breeding lines. In the first study we compared physicochemical analyses of quinoa breeding lines for traits such as water absorption index, crude fat, water solubility, total triterpenoid saponins, ash, crude fiber, total carbohydrates, pasting breakdown, final pasting viscosity, and several other traits and identify breeding lines with superior performance in different end-uses including cookies, hearth bread, pancakes, pan bread, and grain salads. This information is critical in the release and marketing of our varieties to be released in 2021. In FY2020 USDA-ARS lab headed by Dr. Maul has continued evaluation of plant rhizosphere, and endophytic microbe associations, seeking plant beneficial and protective functions. We conducted our third field trial collecting roots, stems, leaves and developing seed heads from select advanced lines provided by the WSU lead team. Endophytic and root associated microbes were isolated using combination of traditional microbiological and advanced metagenomic techniques. Culturable microbes and fungi were enriched using selective microbiological growth media and screened for the traits of phosphorous solubilization, nitrogen fixation (diazotrophic) and antibiotic production using gene targeted PCR, cloning and sequencing. Over three field seasons we have collected over 300 bacterial isolates from the roots and stems of advanced quinoa lines and will conduct advanced screening of isolates in the greenhouse in FY21. Analysis of phosphatase activity and increased/decreased availability of P in the root zone will be evaluated with bacterial strains that show the greatest root zone persistence in the greenhouse studies. We have developed a collaborative relationship with David Sotomayor-Ramírez, Ph.D. Professor of Soil Science, University of Puerto Rico, Mayagüez, PR 00680-9000. Together we have worked on two USDA-NIFA-Hispanic Serving institutions (HSI) program grants to provide funds to support room and board and undergraduate students to complete summer internships with researchers at USDA facilities. The Maul lab mentored one HSI student and two undergraduate students conveying STEM skills such as statistics, bioinformatics plant biology, agronomy and biochemistry. We continued work with our collaborators at Brigham Young University to explore, elucidate, and integrate the genetics of important traits. The ability of American farmers to be engaged in long-term, sustainable organic quinoa production at low altitudes will depend on breeders\' access to diverse sources of genetic-based pest, disease, and heat tolerance. With that goal in mind, researchers at BYU have been collecting quinoa\'s wild sister species, Chenopodium berlandieri (pitseed goosefoot), and developing x quinoa (C. quinoa) cross-populations with selected pitseed goosefoot strains as male parents. At the same time, we have been collecting mostly native diploid species (see chart below) in order to characterize the tertiary gene pool of quinoa breeding resources through DNA sequencing and subsequent phylogenetic analyses to determine which ones are genetically closest to quinoa. Here we will describe activities and results of for approaches outlining these efforts in more detail. 1. Quinoa x Pitseed Goosefoot Breeding: Sets of F6 to F9 lines selected from quinoa (\'Real-1\', \'Surimi\', \'Co407-D\', \'0654\', and \'NL-6\') x pitseed goosefoot (BYU 937, BYU 1301, and BYU 1314) cross populations were subjected to further phenotypic selection in Malawi (LUANAR Experiment Station at Bunda); at the Desert Agriculture Experiment Station in Holtville, CA (spring 2019); at a private farm in Holtville, CA (spring 2020); and at private farms in Aberdeen, ID and Mosca, CO in summer of 2020. Lines were also evaluated at the BYU Kiwanis Park Greenhouse complex in 2020. Interspecies hybrid (F1) plants were also validated via DNA sequence data. 2. Preliminary Phylogenetic Analyses of Wild Chenopodium: Phylogenetic analyses using whole-genome sequence-identified SSRs identified the narrow-leaved C. leptophyllum complex taxa as being closest to the AA subgenomes of the AABB C. berlandieri-hircinum-quinoa biological species complex. This analysis also identified the following: 1) potential South America à North America long-range dispersal involving the South TX AA diploid C. albescens; 2) potential North America à South America long-range dispersal involving the Argentine diploid C. papulosum; the presence of a South American endemic BB diploid, C. obscurum; and 3) a monophyletic origin of the AABB C. berlandieri-hircinum-quinoa biological species complex. 3. Whole-Genome DNA Sequence Analysis of C. berlandieri subsp. nuttaliae: We constructed a reference-quality, chromosome-scale whole-genome DNA assembly of C. berlandieri subsp. nuttaliae var. BYU 1484. This is a waxy genotype of huauzontle from the USDA collection (PI 433231). In short, PacBio CLR long reads, assembly with the canu assembler, were HiC scaffolded to chromosome scale by Phase Genomics. The resulting assembly is the first tetraploid Chenopodium species assembled outside of C. quinoa. 4. C. berlandieri subsp. nuttaliae diversity

panel: To define the diversity base of the wild C. berlandieri germplasm, we are Illumina resequencing (10X) 82 accessions of C. berlandieri varieties, including: vars. zschackei, macrocalycium, berlandieri, boscianum, sinuatum, and subsp. nuttaliae (See Figure 1). Fifty-nine of the accessions have been sequenced, with another 16 currently in queue. The diversity analysis of the C. berlandieri germplasm will represent the Master\'s research for Alex Kimball. **PUBLICATIONS (not previously reported):** 2019/09 TO 2020/08 1. Type: Journal Articles Status: Published Year Published: 2020 Citation: Craine, E.B., K. Murphy (2020). Seed composition and amino acid profiles for quinoa grown in Washington State. Frontiers in Nutrition 7:126. 2. Type: Journal Articles Status: Published Year Published: 2020 Citation: Wieme, R., J.P. Reganold, D. Crowder, K. Murphy, L. Carpenter-Boggs (2020). Productivity and soil quality of organic forage, quinoa, and grain cropping systems in the dryland Pacific Northwest, USA. Agriculture, Ecosystems, and Environment 293: 106838. 3. Type: Journal Articles Status: Published Year Published: 2020 Citation: Eustis, A., K. Murphy, F.H. Barrios-Masias (2020). Leaf gas exchange performance of ten quinoa genotypes under a simulated heat wave. Plants 9: 81. Doi:10.3390/plants9010081 4. Type: Journal Articles Status: Published Year Published: 2020 Citation: Wieme, R., L. Carpenter-Boggs, D. Crowder, K. Murphy, J.P. Reganold (2020). Agronomic and economic performance of organic forage, quinoa, and grain crop rotations in the Palouse region of the Pacific Northwest, USA. Agricultural Systems 177: 102709. 5. Type: Journal Articles Status: Published Year Published: 2019 Citation: Hinojosa, L., M. Sanad, D. Jarvis, P. Steel, K. Murphy*, A. Smertenko (2019). Impact of heat and drought stress on peroxisome proliferation in quinoa. The Plant Journal 99: 1144-1158. doi.org/10.1111/tpj.14411 6. Type: Journal Articles Status: Published Year Published: 2019 Citation: Hinojosa, L., N. Kumar, K.S. Gill, K. Murphy* (2019). Spectral reflectance indices and physiological parameters in quinoa under contrasting irrigation regimes. Crop Science 59: 1927-1944. doi: 10.2135/cropsci2018.11.0711 7. Type: Theses/Dissertations Status: Published Year Published: 2019 Citation: Ashley Eustis, MSc degree, University of Nevada-Reno. Thesis title ﷺEffects of heat stress on the photosynthetic apparatus in quinoa﷽ 8. Type: Conference Papers and Presentations Status: Submitted Year Published: 2019 Citation: Barrios-Masias, F., Eustis, A., Murphy, K. (2019) Leaf carbon assimilation and dark respiration responses to heat stress on quinoa. Oral presentation. ASA? CSSA?SSSA, San Antonio, TX Nov. 10?13, 2019. 9. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Maul, J.E., Emche, S., Ditman, J., Lugo Arroyo, A.M., Bagley, G. 2020. Phosphate Solubilizing Bacteria in the Rhizosphere of Chenopodium quinoa. 2nd International Quinoa Research Symposium Aug. 19, 2020 on-line 10. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Jellen, E. 2020. Genetic Resources & Breeding of Goosefoots (of quinoa). 2nd International Quinoa Research Symposium. August 16-19, 2020. 11. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Maughan, J. 2020. Amaranthaceae Genetic Resources. 2nd International Quinoa Research Symposium. August 16-19, 2020. 12. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Ganjyal, G. 2020. Quinoa End-use Quality and Processing. 2nd International Quinoa Research Symposium. August 16-19, 2020. 13. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Murphy, K. 2020. Contributions of the NPGS to a Decade-Old Quinoa Breeding Program at Washington State University. 2020 CSSA C1-C8 Joint Symposium: Translating Genetic Resources into New, Improved, and Rediscovered Crops. November, 2020. CSSA, ASA, SSSA International Conference. 14. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Murphy, K. 2020. Soil to Society: Developing Crops for Enhanced Human Health and Nutrition. Extension All-unit meeting. February 25, 2020. 15. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Murphy, K. 2020. The Intersection of Agriculture and Human Health at WSU. Inland Northwest Research Symposium. March 27, 2020. 16. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Murphy, K. 2020. Impact of heat stress in quinoa. 2nd International Quinoa Research Symposium. August 16-19, 2020. 17. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Murphy, K. 2020. Developing a postharvest phenotyping platform. 2nd International Quinoa Research Symposium. August 16-19, 2020. 18. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Kellogg, J. 2020. Evolutionary Participatory Quinoa Breeding for Organic Agroecosystems in the Pacific Northwest. 2nd International Quinoa Research Symposium. August 16-19, 2020. 19. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Wieme, R. 2020. Productivity and soil quality in organic dryland crop rotations with quinoa. 2nd International Quinoa Research Symposium. August 16-19, 2020. 20. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Craine, E., K. Murphy. 2019. Essential Amino Acid Content of a World Core Quinoa Collection. 2019 ASA-CSSA-SSSA International Annual Meeting \| Nov. 10-13 \| San Antonio, Texas 21. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Packer, D., E. Craine. 2019. Beyond Yield: Incorporating Nutritional Quality Phenotyping to Quinoa (Chenopodium quinoa) Variety Trials Using Near-Infrared Spectroscopy and X-Ray Fluorescence. 2019 ASA-CSSA-SSSA International Annual Meeting \| Nov. 10-13 \| San Antonio, Texas

2017/09 TO 2018/08 What was accomplished under these goals? In 2018, statewide variety trials were carried out in the following four states: Maryland, Minnesota, Utah, and Washington. Minnesota and Washington proved to be the environments with the highest yields across the cultivars and breeding lines. This information will assist us in determining which variety or varieties to release prior to the close of the grant. Seed is still being processed at the writing of this report, so seed yield and subsequent data will be available in the next report. One of the most common nutritional claims for quinoa is that it is a complete protein. These claims are widely accepted, though they are based only on a few varieties in a few environments. We tested this claim by examining 23 amino acids in 100 quinoa samples from four environments. Our preliminary analysis shows that for adults, many of the quinoa varieties were complete proteins, but a significant portion were not. For infants and young children, a much higher number of the quinoa varieties were not complete proteins, but a significant portion were. The limiting amino acid was most commonly Leucine. This suggest that it is important to select for amino acid content as we develop new quinoa varieties. We are also analying the functionality and consumer preference of different quinoa products. First, we are developing complete seed compositional analysis profiles of our top 25 breeding lines (and multiple others). These lines were grown in our multi-state variety trials and will continue to be analyzed for each year and location moving forward. Our goal is to identify, classify and develop different market classes of quinoa as this information is sorely lacking. The only available market classes are currently based only on seed color, whereas functionality is ignored. Second, we are conducting quinoa baking trials with pan bread, hearth bread and pancakes, where we test different quinoa/wheat ratios for quality, functionalilty and flavor. All our food science and nutritional trials made significant progress this year, and are ongoing through 2019 as well. We continued our heat and drought tolerance trials, and in 2018, two manuscripts were published on heat and/or tolerance in quinoa, and two more submitted. In one submitted manuscript, we showed a correlated peroxisome proliferation with tolerance to heat and drought stress. This could provide a relatively high-throughput method for testing for abiotic stress tolerance in quinoa as we develop new varieties. In a second submitted manuscript, we tested different spectral reflectance indices and physiological parameters in irrigated and non-irrigated treatments for their relationship with yield potential and heat and drought tolerance. We found that NDVI is the most predicitve index for seed yield in quinoa; leaf greeness index was useful for identifying heat tolerance in quinoa. In a different published paper, we showed that pollen viability under heat-stressed conditions is genotype-specific; we were able to identify genotypes with variation in pollen viability under abiotic stress, and the impact on plant growth and seed yield in quinoa. At the University of Nevada, Reno, Ashley Eustis joined the project in Fall 2017 as a graduate student in the MSc Environmental Sciences Program under the guidance of Felipe Barrios Masias. We developed protocols to grow and evaluate quinoa in greenhouses and evaluate responses to heat stress in growth chambers. Plants have been exposed to simulated heat waves based on Pullman, WA data, and we concluded that higher temperatures were necessary to observe better plant responses. Ten genotypes known to differ in heat tolerance were provided by WSU. Evaluations included: 1) Cell membrane stability from plants exposed to heat in growth chambers and from tissue exposed to heat in a laboratory setting. In the laboratory we have evaluated different incubating temperatures to define which one can provide a better separation between genotypes. At least five experiments have been conducted with no less than 120 plants per experiment (10 reps per genotype); 2) Changes in the efficiency of the photosynthetic apparatus using the PhotosynQ (https://photosynq.org/). These measurements have been conducted at pre-dawn and during the day in four round of experiments. Each experiment had at least 120 plants; 3) Leaf gas exchange measurements using the LiCor 6400. Measurements have been conducted in three experiments and two are growing in the greenhouse to conduct measurements before the end of 2018; 4) Leaf respiration using the LiCor 6400. We have conducted preliminary work to understand the effects of high temperatures to respiration. Measurements have been conducted at night. Two experiments are growing in the greenhouse and will be evaluated before the end of 2018; 5) Preliminary work is being conducted with a thermal imaging camera FLIR T530sc. Results so far indicate that quinoa has great capacity to acclimate to high temperatures and doesn\'t show changes in cell membrane stability and leaf gas exchange. We have also observed that the conditions in the greenhouse prior to the experiment (e.g,. minimum and maximum temperature) impact the plant response, and this is going to be taken into consideration for the upcoming experiments. Germplasm Collection:The ability of American farmers to be engaged in long-term, sustainable organic quinoa production at low altitudes will depend on breeders\' access to diverse sources of genetic-based pest, disease, and heat tolerance. With that goal in mind, researchers at BYU have been collecting quinoa\'s wild sister species, Chenopodium berlandieri (pitseed goosefoot). From October 10-11, 2017, Rick Jellen and David Jarvis traveled to Tucson and collected 56 Chenopodium populations in Southeast Arizona. These included 14 populations of pitseed goosefoot (vars. sinuatum and zschackei) as well as populations of diploid C. arizonicum, C. fremontii, C. neomexicanum, C. palmeri, C. sonorense, and C. watsonii. During the period April 19-21, 2018, Jellen, Jarvis, and Jeff Maughan flew to South Texas and collected seed from 23 populations of the berlandieri interior ecotype, six populations of the Gulf Coast boscianum ecotype, plus seven populations of putative diploid C. albescens. Jellen collected two populations of the sinuatum ecotype of C. berlandieri above Malibu, California on June 13. On September 20-24 Jellen and Maughan flew to New England and collected nine populations of the Atlantic Coast macrocalycium ecotype. From October 3-5, Jellen

and a student flew to Oklahoma and collected eight populations of the sinuatum ecotype, four of the zschackei ecotype, and eight populations of a unique ecotype with intermediate characteristics between vars. sinuatum/zschackei and berlandieri, along with numerous narrow-leaved diploid Chenopodium populations. ?Genome Wide Association Studies: Sequencing A total of 479 samples of quinoa (Chenopodium quinoa) were genotyped using tGBS® Genotyping by Sequencing technology with the restriction enzyme Bsp1286I. Samples were sequenced using an Illumina HiSeq X instrument, and reads were aligned to the Chenopodium quinoa v1.0 reference genome after debarcoding and trimming. SNP calling was conducted using only those reads that align to a single location in the reference genome. The genotyping was contracted out to Freedom Markers who generated several sets of SNPs within the population. The first set termed \"ALL SNPs\" is a less stringent SNP set containing 309,224 SNP sites. A second (more stringent, higher quality) set of 198,288 SNP sites was also produced wherein each SNP site was genotyped in at least 50% of the samples and to as MCR50 SNP set. Each of these SNPs is supported on average by 31 tGBS reads/SNP/genotyped sample. **PUBLICATIONS (not previously reported):** 2017/09 TO 2018/08 1. Type: Journal Articles Status: Accepted Year Published: 2018 Citation: Murphy, K., J. Matanguihan, F. Fuentes, L. Gomez-Pando, R. Jellen, J. Maughan, D. Jarvis (2018). Advances in quinoa breeding and genomics. Plant Breeding Reviews (accepted, in press). 2. Type: Journal Articles Status: Published Year Published: 2018 Citation: Hinojosa Sanchez, L., J. Matanguihan, K. Murphy* (2018). Effect of high temperature on pollen morphology, plant growth and seed yield in quinoa. Journal of Agronomy and Crop Science (available online) https://doi.org/10.1111/jac.12302. 3. Type: Journal Articles Status: Published Year Published: 2017 Citation: Wu, G., C. Morris, K. Murphy (2017). Quinoa starch characteristics and their correlations with the texture profile analysis (TPA) of cooked quinoa. Journal of Food Science 82: 2387-2395. 4. Type: Journal Articles Status: Submitted Year Published: 2019 Citation: Noratto, G.D., K. Murphy, B.P. Chew (submitted August 2018). Quinoa intake reduces plasma and liver cholesterol, lessens obesity-associated inflammation, and helps to prevent hepatic steatosis in obese db/db mouse. Journal of Functional Foods. 5. Type: Journal Articles Status: Under Review Year Published: 2019 Citation: Sankaran, S., C.Z. Espinoza, L. Hinojosa, X. Ma, K. Murphy. High-throughput field phenotyping to assess irrigation treatment effects in quinoa. Sensors. 6. Type: Journal Articles Status: Submitted Year Published: 2019 Citation: Hinojosa, L., M. Sanad, D. Jarvis, P. Steel, K. Murphy*, A. Smertenko*. Peroxisome proliferation correlates with tolerance to heat and drought stress. Plants. 7. Type: Journal Articles Status: Under Review Year Published: 2019 Citation: Gardner, M., M.F.A. Maliro, K. Murphy, J.R. Goldberger. Assessing the potential adoption of quinoa for human consumption in central Malawi. Agriculture and Food Security. 8. Type: Journal Articles Status: Under Review Year Published: 2019 Citation: Hinojosa, L, J.A. Gonzalez, F.H. Barrious-Masias, F. Fuentes, K. Murphy. Quinoa abiotic stress responses: A review. Plants. 9. Type: Theses/Dissertations Status: Published Year Published: 2018 Citation: Leonardo Hinojosa, Ph.D. in Crop Science, Graduated Fall 2018 Dissertation: Effect of Heat and Drought Stress in Quinoa (Chenopodium quinoa Willd.) 10. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Halle Choi, Alecia Kiszonas, Carolyn Ross, Craig F. Morris and Kevin M. Murphy. 2018. Effect of two quinoa flour blends on the chemical and physical properties of pancakes, pan bread and hearth bread. ASA-CSSA Annual Meeting, Baltimore, MD, 2018. 11. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Craine, E., K. Murphy. Seed Composition and Amino Acid Profiles for Quinoa Accessions Grown in Washington State. ASA-CSSA Annual Meeting, Baltimore, MD. 2018. 12. Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Cedric Habiyaremye, David White, Daniel Packer, Kurtis L. Schroeder and Kevin M. Murphy. Effect of Nitrogen and Seeding Rate on Plant Height, Seed Maturity and Seed Yield of Quinoa and Hulless Barley Grown in No-till in the Palouse. ASA-CSSA Annual Meeting, Baltimore, MD. 2018.

2016/09 TO 2017/08 What was accomplished under these goals? In the first year of this project we were able to 1) initiate and carry out a multi-state quinoa variety and breeding line trial (see objective 1); 2) conduct two agronomic trials which addressed the problem of finding the best management practices for quinoa in organic systemes across differing environments (see objective 2). Objectives 3 through 5 are underway and we expect positive results on these research topics after year 2 of the project. Objective 6 was reached through multiple oral and poster presentations, an extension bulletin, research papers, and field days and workshops in Year 1. This will continue throughout the project. **PUBLICATIONS (not previously reported):** 2016/09 TO 2017/08 1. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Hinojosa, L., K. Murphy (2017). Evaluation of quinoa pollen under high temperature conditions. National Association of Plant Breeders, Davis, CA, August 8, 2017. 2. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Habiyaremye, C., D. Packer, K.L. Schroeder, K. Murphy (2017). Effect of nitrogen and seeding rate on plant height, seed maturity and seed yield of quinoa and hulless barley grown in no-till farming systems in the Palouse. WSU BIOAg Symposium, Pullman, WA, March 1, 2017. 3. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Hinojosa, L., K. Murphy (2017). Evaluation of quinoa genotypes under heat and drought field conditions. WSU BIOAg Symposium, Pullman, WA, March 1, 2017. 4. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Hinojosa, L., K. Gill, N.

Kumar, K. Murphy (2016). High-throughput phenotyping to evaluate heat stress response in quinoa. ASA-CSSA-SSSA International Annual Meeting, Phoenix, AZ, November 7, 2016. 5. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Murphy, K. (2017). Breeding quinoa for novel environments in the climate change era. Agriculture and Climate Change Conference, Sitges, Spain, March 25, 2017. 6. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Murphy, K. (2017). Alternative crop production in the PNW. Cascadia Grains Conference, Olympia, WA, January 6, 2017. 7. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Murphy, K. (2016). Quinoa cultivation in western North America: Lessons learned and the path forward. ASA-CSSA-SSSA International Annual Meeting, Phoenix, AZ, November 8, 2016. 8. Type: Journal Articles Status: Published Year Published: 2017 Citation: Wu, G., C. Morris, K. Murphy (2017). Quinoa starch characteristics and their correlations with the texture profile analysis (TPA) of cooked quinoa. Journal of Food Science 82: 2387-2395. 9. Type: Journal Articles Status: Published Year Published: 2017 Citation: Aluwi, N.A., K. Murphy, G.M. Ganjyal (2017). Physicochemical characterization of different varieties of quinoa. Cereal Chemistry 94: 847-856. IF=2.402. (10. Type: Journal Articles Status: Published Year Published: 2017 Citation: Wu, G., C.F. Morris, K. Murphy, C.F. Ross (2017). Lexicon development, consumer acceptance, and drivers of liking of quinoa varieties. Journal of Food Science 82: 993-1005. IF=1.649. 11. Type: Journal Articles Status: Published Year Published: 2017 Citation: Maliro, M.F.A., V.F. Guwela, J. Nyaika, K. Murphy (2017). Preliminary studies of the performance of quinoa (Chenopodium quinoa Willd.) genotypes under irrigated and rainfed conditions of central Malawi. Frontiers in Plant Science 8: 227. 12. Type: Journal Articles Status: Published Year Published: 2017 Citation: Jarvis, D.E., Y.S. Ho, D.J. Lightfoot, S.M. Schm?ckel, B. Li, T. Borm, H. Ohyanagi, K. Mineta, C.T. Michell, N. Saber, N.M. Kharbatia, R.R. Rupper, A.R. Sharp, N. Dally, B. Boughton, Y.H. Woo, G. Gao, E. Schijlen, X. Guo, A.A. Momin, S. Negr?o, S. Al-Babili, C. Gehring, U. R?ssner, C. Jung, K. Murphy, S. Arold, T. Gojobori, G. van der Linden, R. van Loo, E.N. Jellen, P.J. Maughan, M. Tester (2017). The genome of Chenopodium quinoa. Nature 542: 307-312. 13. Type: Theses/Dissertations Status: Published Year Published: 2017 Citation: Kristofor Ludvigson, M.S. in Crop Science, Graduated Summer 2017 Thesis: Alternative Planting and Weed Control Methodology for Certified Organic Quinoa Production in Western Washington State 14. Type: Theses/Dissertations Status: Published Year Published: 2017 Citation: Julianne Kellogg, M.S. in Crop Science, Graduated Spring 2017 Thesis: Evolutionary Participatory Quinoa Breeding for Organic Agroecosystems in the Pacific Northwest Region of the United States

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Addressing the Needs of Organic Direct-market Growers for Production and Quality Traits in Vegetable Seed

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Project No.	WIS01959
Agency	NIFA WIS\
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Performing Institution	UNIV OF WISCONSIN, 21 N PARK ST STE 6401, MADISON, WISCONSIN 53715-1218

NON-TECHNICAL SUMMARY

It is well established that organic breeding priorities can be different than conventional priorities and that breeding in organic systems is critical to developing the best varieties for organic agriculture (Myers and Lammerts van Bueren, 2012). The organic seed sector is growing, and more organic farmers are using certified organic seed now than they were five years ago (OSA, 2016). Partly because of the decentralized nature of the organic seed industry and the regionalism of organic production systems, we still lack information on organic variety use and development, and, while we have good information on general traits of importance, we do not have detailed information on how farmers make variety choices when there are tradeoffs among these important traits. In particular, there is a need to balance quality and production traits, and in direct market situations, quality is often of great importance, and informal conversations with growers suggest that they cannot compromise on quality traits, even if it means accepting less than optimal production.It is important for breeders and the seed industry to better understand the constraints that growers may face when choosing varieties and to strategically plan how to improve production in varieties that meet quality standards for these markets. While the decentralized nature of the organic seed industry is one of its strengths, there is a need for a better understanding of priority issues for the fresh market vegetable seed sector nationally, so that breeders working on these crops in the public, private and non-profit sectors are aware of needs in different regions and market classes. This will result in better coordination of limited resources to effectively meet the needs of organic growers as well as better outreach efforts to make seed professionals and farmers aware of relevant breeding efforts. As a result of this project, there will be increased communication between breeders, organic farmers and interested consumers during and after the grant period. This will help plant breeders better meet the needs of farmers growing for local organic markets where quality is critical to success. Varieties with improved characteristics for organic farmers will contribute to increased organic vegetable production for direct markets, and increased availability of high quality organic produce for consumers.

OBJECTIVES

The long-term goals of this project are 1) to develop specific priorities for vegetable variety development for organic systems, that will lead to the release of varieties with high value for organic farmers, 2) to improve our

understanding the traits needed in organic fresh market vegetable systems, and how these may differ from one region to another or among different marketing strategies 3) to develop a strategy for breeding for these priority traits involving breeders in the public, private and non-profit sectors, seed companies, farmers and consumers.Multiple surveys and meetings in the past two years have sought to identify priority traits for organic farmers. The lack of desirable genetic traits is still one of the major reasons cited by organic vegetable growers for not using organic seed, higher than other categories of crops. We have good baseline data on general traits of importance, but lack a plan of action for addressing these needs, and in many cases do not fully understand how farmers evaluate tradeoffs in essential trait combinations for particular crops and markets. This proposal is unique in that it will use priorities and recommendations from farmers to guide a detailed planning process with the organic fresh market vegetable seed industry and breeders to concretely plan to address the unique needs of organic direct market vegetable growers.As a result of this project, there will be increased communication between breeders, organic farmers and interested consumers during and after the grant period. This will help plant breeders better meet the needs of farmers growing for local organic markets where quality is critical to success. Varieties with improved characteristics for organic farmers will contribute to increased organic vegetable production for direct markets, and increased availability of high quality organic produce for consumers.

APPROACH

1. Phone survey of key people involved in the organic seed industry and breeding for organic direct market vegetable growers: (A) Regional field representatives of seed companies specializing in organic vegetable seed for direct market growers. The seed company directories of the Organic Seed Alliance, ATTRA Organic Seed Suppliers, and attendance lists from the Organic Seed Growers Conference and regional organic conferences will be used to create a list of interviewees. Primary questions will focus on what kinds of varieties growers are asking for, what traits they have asked for that are not available and where growth is for fresh market vegetable crops and market classes. (B) Plant breeders working on organic and fresh market vegetables at public universities, non-profits and private seed companies. These breeders will be identified from the interviews of companies surveyed in part (a) as having developed varieties for organic growers, and from the online survey of seed and variety sources in part 2 below. (C) Organic produce purchasers: produce managers at cooperative groceries and other stores specializing in local organic produce, chefs, farmers\' market managers and others with insights into needed traits. These individuals know what is necessary to make a variety successful on the retail end, and are familiar with trends in produce consumption and demand that may affect breeding priorities for the near to mid-term. Individuals will be identified in major organic markets, to represent different consumer demographics. We will also identify individuals representing different scales of produce purchasing, from larger grocery stores operating at a regional or national level, to single-store cooperatives and local farm-to-table restaurants. We will not attempt a comprehensive survey of this group, as this would be a much larger project, but instead will identify individuals with significant experience purchasing organic produce directly from farmers, and with an understanding and appreciation of the importance of plant breeding for organic systems.2. Online survey of a subset of respondents to State of Organic Seed report who responded that they primarily grow vegetable crops: Organic vegetable growers will be asked to identify where they purchase organic seed, which traits are most important to them when selecting varieties, and which trait combinations they feel are lacking. This will be distinct from the State of Organic Seed report, which asked what traits were most in need of improvement, without asking which traits farmers felt were most critical to their variety choices. Knowing which traits growers cannot compromise on, which traits they wish they could find together in one variety and which traits they feel are most in need of improvement in the varieties that they are currently using will create a complementary and more complete picture of breeding needs for organic direct market vegetables. For example, the majority of growers ranked disease resistance as the top priority in organic vegetables, but without information on which varieties they are currently growing and how they pick those varieties, we do not know whether they are growing the most disease resistant varieties on the market or varieties with little disease resistance but excellent flavor. In fact, many informal conversations with growers have suggested that they are not growing the most disease resistant varieties because they find the flavor lacking and have difficulty selling varieties with poor flavor. They see improved disease resistance in varieties that meet their market demands as a critical priority for breeding. The online survey and more detailed phone interviews in part 1 will attempt to identify these nuances and more systematically define breeding priorities. Follow up phone interviews with selected respondents to the online survey will aid in interpretation of results.3. Planning workshop with the organic seed industry and breeders, in Madison, WI: Participants will include breeders and regional seed representatives from several organic seed companies, vegetable breeders with organic selection programs from universities and non-profit organizations, organic vegetable farmers who have done significant amounts of variety trialing with either companies or non-profit/public sector programs, and representatives of organic consumers. These individuals will be selected for their knowledge of existing breeding efforts for organic direct-market growers and their engagement in the variety development process and organic seed sector. The planning workshop will take place around the second week of

January, 2017, Monday afternoon to Wednesday morning. On the first afternoon, results from existing surveys (summarized above) and from the phone and online survey conducted as part of this proposal will be discussed. The second day will be dedicated to specific crop discussions, which will include prioritizing traits identified from the surveys, and identifying which breeding programs and seed companies are working on those crops/traits along with areas of potential collaboration. Regional and market specifics will be included in these discussions. The morning of the third day will be spent summarizing recommendations and next steps, and preparing for presenting the findings to growers, other stakeholders and the public.Workshop Invitees:Adaptive Seeds (Oregon), AP Whaley Seeds (Wisconsin), Bejo Seeds (International), Charlie Brummer (University of California - Davis), Commonwealth Seed Growers (Virginia), Jeanine Davis, (North Carolina State University), Fruition Seeds (New York), Irwin Goldman (UW Madison), High Mowing Organic Seeds (Vermont), Hudson Valley Seed Library (New York), Johnny\'s Selected Seeds (Maine), Michael Mazourek (Cornell University), Jim Myers (Oregon State University), Organic Seed Alliance (National), Prairie Road Organic Seeds (North Dakota), Sierra Seed (California), Phil Simon (UW Madison), Southern Exposure Seed Exchange (Virginia), Danielle Treadwell (University of Florida), Bill Tracy (UW Madison), Vitalis Organic Seeds (International), Wild Garden Seeds (Oregon), Farmer and consumer representatives to be determined based on phone interviews and survey results. Seed industry and public sector breeder lists will also be refined based on these results. **Progress** 09/01/16 to 08/31/17 **Outputs** Target Audience: The target audiences were organic farmers, plant breeders the organic seed industry and organic produce purchasers including retail, restaurants and consumers. We reached all these audiences, with a focus on farmers, plant breeders and the organic seed sector. We conducted phone interviews and had a full-day workshop with breeders and the seed sector, as well as workshops and roundtables for farmers at several winter conferences. We also conducted outreach activities for consumers and other produce purchasers, particularly chefs. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Several graduate students in the UW-Madison plant breeding and plant genetics program were able to attend the day-long workshop in person, and others attended virtually. This gave them the opportunity to meet public sector plant breeders, private sector plant breeders and other professionals in the organic seed industry. How have the results been disseminated to communities of interest?The proceedings have been distributed to all participants in the workshop and phone interviewees, as well as others in the organic seed and farming community. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? Organic Growers Survey- The Organic Growers Survey was designed by members of the project team, and was based in part on a successful survey conducted by Lyon et al. in 2012, aimed at accessing organic farmers plant breeding priorities in Wisconsin. The survey was also designed as a supplement to the State of Organic Seed (SOS) survey and report, released in 2016. While the SOS survey targeted farmers' opinions on organic seed availability, accessibility and quality, it did not elicit responses about priority traits for specific crops. The survey was designed using survey monkey. An initial draft was sent to small pilot group of 8 organic vegetable farmers around the country. Their feedback was incorporated into a final draft distributed to 279 farmers using the Organic Seed Alliance farmer and seed grower lists, as well as the SOS distribution list. Additional farmers were reached through farmer organizations, such as Midwest Organic and Sustainable Education Services (MOSES), who distributed the survey through their e-mail lists. Survey responses were compiled automatically and exported into Microsoft Excel spreadsheets. Responses were analyzed and graphs were created using the R package tm (Feinerer, Hornik and Meyer 2008). Plant Breeder and Seed Company Interviews- 27 vegetable breeders and seed company representatives were interviewed about gaps in organic seed availability and cultivar development, barriers to releasing or offering more organic cultivars, and whether/how a national trialing network for organic cultivars would be useful. Staff at UW-Madison, Oregon State University and the Organic Seed Alliance conducted interviews by phone and in-person when possible. Plant breeders were interviewed about plant breeding priorities and specific traits important to organic farmers, with regard to their crop(s) of expertise. Seed company representatives were asked to select three or four crops to discuss, based on where their customers have identified gaps in availability of organic cultivars, or specific traits important to organic farmers. Interview participants were recruited from the known network of university, seed company and independent plant breeders who develop vegetable crops for organic environments, and from the pool of small to medium-sized seed companies who offer organic seed of cultivars bred for organic systems. Interview participants are listed in Table 2. Interview results were compiled in an excel spreadsheet and analyzed qualitatively for common themes. The Organic Variety Trialing and Plant Breeding Strategy Summit- Held in Madison, Wisconsin on February 22, 2017. The goals of this meeting were to 1) define realistic objectives for the proposed national organic variety trialing network and awards system, agree on a basic structure for these programs, and articulate near-term next steps for bringing them into being. The results from the meeting, survey and phone calls are described in the meeting proceedings distributed to all participants. The general conclusion from the summit was that participants are enthusiastic about pursuing a national organic variety trialing program and some sort of affiliated recognition program for outstanding organic varieties and breeders. A series of \"next steps\" were outlined at the end of the Summit. Working groups were established to discuss pilot trials at the hub sites, data sharing protocols, cost

estimates for trials, surveying other related trial initiatives, communications protocols and a statement of ethics for exchanging germplasm and data. These working groups will convene in the fall and winter of 2017-2018 in preparation for the 2018 season. The first \"next step\" would be to formally establish hub sites, each with an advisory board of local farmers, researchers, and breeders or seed companies. Each hub site would need to develop an estimate of the time and cost necessary to manage trials and collect the desired data. Participants agreed to discuss a potential 'pilot' crop in the 2018 growing season with a few varieties incorporated into existing trialing activities, to test data sharing strategies. Formally selecting crops and traits for the early years of the trial is also a priority for the project leadership. This will be done in consultation with experts on each of the candidate crops discussed above, and in reference to the farmer survey and plant breeder interviews. Surveying other complementary trialing initiatives is also a priority. This would help identify potential overlaps and complementary activities, and reduce the risk of redundancy. Setting up a website similar to Organic Seed Alliance's online platform is an important first step in implementing the program's communication strategy. Having project information housed online will help with outreach and participant recruitment. The website would also serve as a portal to the data sharing platform, which participants will continue to research and re ne, ideally with the help of some data engineering students. Finally, the group decided it is important to begin reaching out to partners in unrepresented regions. The South, Southwest, Mountain, and Central US were identified as locations for potential partnerships, as well as some sites in Canada, where partners affiliated with the Bauta Family Initiative on Canadian Seed Security have established trialing or seed production initiatives. While the project may be limited in its early years to the five initial hub sites, it is important to build relationships with partners in other areas, both as potential future hub sites, and to ensure that the project remains inclusive of many different organic seed initiatives. An OREI proposal was submitted in January 2017 but was not funded. A revised proposal, with the full results of the planning grant, will be submitted in 2018.

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Organic Alternatives to Conventional Celery Powder as a Meat Curing Agent: Orei Planning Grant

Accession No.	1010459
Project No.	WIS01958
Agency	NIFA WIS\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2016-51300-25733
Proposal No.	2016-04459
Start Date	01 SEP 2016
Term Date	31 AUG 2017
Grant Amount	$38,564
Grant Year	2016
Investigator(s)	Silva, E. M.
Performing Institution	UNIV OF WISCONSIN, 21 N PARK ST STE 6401, MADISON, WISCONSIN 53715-1218

NON-TECHNICAL SUMMARY

Organic meat products are one of the fastest growing segments of organic agriculture in the United States. More specifically, organic cured meat products have shown promising market growth, supporting further use of organically raised animals and allowing for greater sustainability and profitability of the organic livestock industry. However, due to regulatory changes that will limit the current availability of organic-compliant curing agents, it is critical that the industry explore and ensure the production of an alternative organic source of nitrate, either as organic celery powder from an organically grown celery crop, or from an another organically grown crop. We propose to bring together a national group of stakeholders and supporters - farmers, industry, researchers, and extension personnel - to establish a consortium of expertise (Organic Curing Powder Working Group) invested in finding solutions that address current and future needs of organic cured meat processors. We will benefit organic rotations biologically and economically while supporting the overall continued growth of the industry.

OBJECTIVES

Working closely with stakeholders, the goal of this planning proposal is to develop a roadmap of research and extension activities that will provide the organic cured meat industry with solutions to the critical and imminent issue: the lack of availability of organic curing powder, without which the industry could be prevented further growth and erosion of market share. Through project activities, we will gain clearer understanding of holistic strategies to ensure an adequate quantity of curing powder from an organically produced crop to meet the needs of the expanding organic processed meat industry. Successful completion of this planning process will result in the formation of an expanded Organic Meat Curing Powder Working Group and submission of integrated multiregional proposal(s) to USDA-NIFA in response to the request for application for the OREI program in 2017.The four project objectives are:Objective 1: Individual stakeholder interviews and needs assessment. Objective 2: Asset and Resource MappingObjective 3: Working Group MeetingObjective 4: Development and submission of integrated proposals Project Methods Objective 1: Individual stakeholder interviews and needs assessment: Methodology: Interviewees will initially be drawn from the stakeholders already committing support to this project (see letters of support). From there, snowball-sampling techniques will be used to identify key farmers, processors, researchers, and extension personnel who should be engaged in the discussion. The

current working group includes members who are knowledgeable about production and processing of raw product, as well as the production of cured meat products, allowing a robust base for the interviews. The PD's program has experience with focus group and individual farmer interviews (Silva et al., 2014; Lyon et al., 2015). These activities will be completed by October 2016.Objective 2: Asset and Resource Mapping: Methodology: To achieve this objective, we will use a combination of geographic information system (GIS) and optimization techniques to analyze the capacity of the organic cured meat industry to meet their curing powder needs within the coming decade. We will identify regions across the U.S. within which organic celery could potentially be grown, taking into account current crop rotations and potential further diversification of rotations. Additionally, we will identify alternative organic or potentially transitioned acres that could be used for alternative crops for extraction, including cover crops or alternative vegetable crops. Key inputs, such as supply of available fertilizers and equipment, will be taken into account. Additionally, we will identify regions in which oversupply of nutrients (e.g., areas with high concentrations of livestock supplying excess manure resources) remains a concern and which could benefit from the production of nitrogen scavenging crops. We will also locate currently and potentially available processing facilities, to which raw crop product could be shipped for further processing. These models will enable the generation of maps for visualizing the geographic extent of raw and processed product supply. These activities will occur concurrently to those outlined in Objective 2 and be completed by October 2016.Objective 3: Working Group Meeting: Methodology: The facilitator, in consultation with the PD, collaborators and OTA representatives, and guided by the results of Obj. 1 and 2, will compile an industry overview and summary of activities to date to serve as an introduction to the day-long meeting. After presentation of the results, the meeting participants will then convene in small groups to respond to key themes that have emerged throughout project activities, identifying both existing and needed resources to address current barriers. The participants will report back to the larger group, where research and extension directions, as well as key industry partnerships, will be generated to inform activities and future grant proposals.Objective 4: Development and submission of integrated proposals: Methodology: Approximately 10 stakeholders (farmers and industry personnel) and researchers from the working group will be more intimately involved in the development of research proposals for submission to the OREI, AFRI, and other USDA programs. A general outline for this proposal will be developed as an outcome of Objective 3, with proposals tailored for various funding opportunities. Submissions will be prepared from February 2017 through June 2017. **FINAL REPORT** 09/01/16 to 08/31/18 Outputs Target Audience:The target audience for this project were the organic industries that are reliant on a supply or organic celery powder to maintain and/or expand their production of cured meat products. This included producers and purveyors of organic jerky, bacon, and sausage. Additionally, the target audience included organic farmers for which the expanded need for and production of organic celery could serve as an additional market opportunity. Changes/Problems:No major changes in the approach occurred; however, the completion of the project was delayed due to the departure of Anders Gurda to an industry position. A no-cost extension was requested and granted from the funding agency, and the project was successfully completed. What opportunities for training and professional development has the project provided?This project led to further professional training for Anders Gurda, who completed the interviews under the mentorship of Dr. Silva. Mr. Gurda has since moved on to an industry position within the organic sector. How have the results been disseminated to communities of interest?Initial results were disseminated at the meeting in Pacific Grove, CA prior to the EcoFarm conference. Approximately 25 individuals attended a 5-hour planning meeting, including members of the organic vegetable community (Earthbound Farms, organic vegetable farmers), cured meat processors (Organic Valley, Applegate), celery powder processors (Kerry Foods), marketers (Whole Foods) and other players across the celery powder/cured meat supply chain. Results were distributed to project partners at the end of the project through a final white paper. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Objective 1: Develop an in-depth understanding of the research and extension needs of the organic cured meat industry through individual interviews As of now, the research needs outweigh the Extension needs of the industry. We identified the following primary research needs: 1. For processing companies to be better able to contract the appropriate number of organic celery acres and accurately anticipate nitrate yields, it is critical that we assess the impacts of nitrogen (N) fertility, genetics, and environment on nitrate levels in organic celery grown in key regions throughout the U.S. (California, Florida, and the upper Midwest). Also, to expand the production niches in which to grow the crop, and to facilitate weed management on larger acreages, we need to further investigate alternative sources of plant-based nitrate, including known nitrate accumulators such as chard, and beets. For all these crops, not only does the level of nitrate in the plant tissue need to be determined, but the resulting nitrate: nitrite conversion efficiency, which has anecdotally been observed to differ in organic vs. conventional crops. 2. Sensory and quality evaluation of cured meat products must be conducted specifically using organic vegetable powder, particularly those from non-celery based sources, to ensure no changes in quality. 3. Economic and market assessments must be done of both the production of organic celery powder and related cured meat products, to better anticipate impacts on the current and projected volumes sold and profitability of this sector of the organic market. Objective 2: Create an asset and resource map to strategize where research and extension

investments should be made. The asset and resource map was created to describe key needs for the industry to attain an adequate supply of organic celery powder. This information was integrated in the January 2018 OREI submission. Objective 3: Verify and validate the findings at a Working Group meeting, executing a planning integrated agronomic, economic, and processing research and extension programs This objective was completed in January 2017, with a meeting in Pacific Grove, CA prior to the EcoFarm conference. Approximately 25 individuals attended a 5-hour planning meeting, including members of the organic vegetable community (Earthbound Farms, organic vegetable farmers), cured meat processors (Organic Valley, Applegate), celery powder processors (Kerry Foods), marketers (Whole Foods) and other players across the celery powder/cured meat supply chain. Objective 4: Submit integrated proposal(s) to address research and extension needs This objective was completed in July 2016, January 2017, and January 2018. Additional funds were secured from Organic Valley to conduct initial field and lab testing on nitrite levels of crops and nitrate: nitrite conversion efficiency. A full proposal was submitted to the USDA-OREI program, involving and interdisciplinary team (crop scientists, meat scientists, economists, and industry partners). We then resubmitted the proposal in 2018 - although it was not funded, it did reach the \"outstanding\" category.

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Enhancing Animal Care Strategies on Organic Dairy Farms

Accession No.	1010693
Project No.	MIN-02-G02
Agency	NIFA MIN\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2016-51300-25734
Proposal No.	2016-04461
Start Date	01 SEP 2016
Term Date	31 AUG 2019
Grant Amount	$1,400,940
Grant Year	2016
Investigator(s)	Heins, B. J.

NON-TECHNICAL SUMMARY

The safeguarding of animal health and welfare is a core value of organic dairy production and the main driver for the success of dairy farming. Impactful and cost-effective prevention and treatment approaches are needed to provide optimal care to animals. Over the past decade organic dairy producers and their veterinarians from across the United States, have repeatedly expressed their need for more evidence-based preventive and curative animal care practices. Most commonly, organic dairy producers identified mastitis, lameness, reproductive and calf health as the health challenges for which they need more evidence-based data for treatment and control. The proposed work will evaluate innovative preventive and curative approaches for mastitis, digital dermatitis (lameness), reproductive disorders, calf health and fly management under field conditions on organic dairies across the Nation. Results of these studies, including economic analysis, will be shared with organic dairy producers. Furthermore, an online resource and short courses about effective prevention and treatment approaches will be developed for veterinarians so that they can advise their clients within a valid veterinary-client-patient-relationship.

OBJECTIVES

The safeguarding of animal health and welfare is a core value of organic dairy production and the main driver for the success of dairy farming. Impactful and cost-effective prevention and treatment approaches are needed to provide optimal care to animals. The proposed work will evaluate innovative preventive and curative approaches for mastitis, digital dermatitis (lameness), reproductive disorders, calf health and fly management under field conditions on organic dairies across the Nation. Results of these studies, including economic analysis, will be shared with organic dairy producers. Furthermore, an online resource and short courses about effective prevention and treatment approaches will be developed for veterinarians so that they can advise their clients within a valid veterinary-client-patient-relationship. The long term goal of this proposal is to improve the profitability of organic dairy farms by providing evidence-based and economically sound animal care solutions to producers and their veterinarians. The ultimate long term goal of this research and our outreach activities is to improve the profitability of organic dairy farms by providing evidence-based and economically sound animal care solutions to producers. **Project Methods** We will explore preventive and therapeutic methodologies focused on improving overall health and cow wellbeing and we will additionally assess the economic impact of these procedures through cost-benefit analysis. The field trials focus on diseases that were identified by producers as important to them. The selected interventions were based on a) currently used, but unevaluated, management practices and b) modifications of practices that were used successfully in other areas (e.g. fly leg wraps for

horses) and could be used on organic dairy farms as well. The majority of the work will be conducted on large organic dairy herds to simplify the logistical access to the large number of animals needed for this kind of research and to allow for a standardization of management practices. Demonstration projects on smaller stakeholder farms will add to information about the feasibility of methods for smaller farms without burdening small farms with the intense required sampling. Results of these studies will be incorporated in the developed outreach efforts. **Progress** 09/01/16 to 08/31/21 **Outputs** Target Audience:We have reached organic dairy farmers, veterinarians, and organic dairy industry representatives across the Upper Midwest region.We delivered a successful organic field day in August 2021 at the West Central Research and Outreach Center, Morris, MN that provided information on enhancing animal welfare of dairy cattle.Through this project we reached over 2,000 organic dairy farmers.The field days were conducted for organic dairy producers, extension educators, veterinarians, and organic industry personnel. We educated 15 undergraduate college students through internships that focused on organicfly control, alternative treatments for dairy cattle, calf rearing strategies to improve animal health and milking procedures to improve animal health of first-lactation heifers at the WCROC. The project also educated and trained 7graduate students with this project. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project has trained organic dairy producers on the control of animal health for organic dairy cattle. Many extension educators and organic industry representatives were informed on organic dairy management practices at field days and conferences. We havetrained 12 undergraduate students on how to conduct research and outreach in an organic situation. Graduate students from Minnesota and Colorado presented research on organic animal health at the 2021 Virtual American Dairy Science Association meeting. How have the results been disseminated to communities of interest?Weoffered an organic dairy day at the University of Minnesota West Central Research and Outreach Center to provide farmers and other industry personnel tools to enhance animal care on organic dairy farms. During the last year, over 50 people have attended the field days at the WCROC. Over 250 people have attended presentations related to the objective research in the project. Results are also disseminated to academic and veterinary audiences through peer-reviewed publications and abstracts presented at conferences. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** (N/A) **Publications** - Type: Journal Articles Status: Published Year Published: 2021 Citation: Phillips, H.N. and B. J. Heins. 2021. Evaluation of an herbal therapy to alleviate acute pain and stress of disbudded dairy calves under organic management, Translational Animal Science, Volume 5, Issue 2, April 2021, txab044, https://doi.org/10.1093/tas/txab044 - Type: Journal Articles Status: Published Year Published: 2021 Citation: Phillips, H.N.; Heins, B.J. Effects of Outdoor Stocking Density on Growth, Feather Damage and Behavior of Slow-Growing Free-Range Broilers. Animals 2021, 11, 688. https://doi.org/10.3390/ani11030688 - Type: Journal Articles Status: Published Year Published: 2021 Citation: Phillips, H.N.; Sorge, U.S.; Heins, B.J. Effects of Pre-Parturient Iodine Teat Dip Applications on Modulating Aversive Behaviors and Mastitis in Primiparous Cows. Animals 2021, 11, 1623. https://doi.org/10.3390/ani11061623 - Type: Other Status: Published Year Published: 2021 Citation: Heins, Brad. 2021. Milk Price, somatic cell count, for the WCROC dairy farm. Dairy Star. January 16, 2021 - Type: Journal Articles Status: Published Year Published: 2021 Citation: Pinedo, P., Manr&#xfffd;quez, D., Marotta, N. et al. Effect of oral calcium administration on metabolic status and uterine health of dairy cows with reduced postpartum rumination and eating time. BMC Vet Res 17, 178 (2021). https://doi.org/10.1186/s12917-021-02881-2 - Type: Journal Articles Status: Published Year Published: 2021 Citation: Gilberto Solano-Su&#xfffd;rez, Luciano S Caixeta, Alexander Masic, Diego Manr&#xfffd;quez, Luciana Hatamoto-Zervoudakis, Sushil Paudyal, Ana Velasquez-Munoz, Juan Velez, Pablo J Pinedo, Effect of peripartal administration of mycobacterium cell wall fraction on health and fertility of Holstein cows under organic-certified management, Journal of Animal Science, Volume 99, Issue 9, September 2021, skab191, https://doi.org/10.1093/jas/skab191 - Type: Journal Articles Status: Published Year Published: 2021 Citation: S. Paudyal, J.E. Lombard, P. Melendez, I.N. Roman-Muniz, R.J. Callan, F. Maunsell, P. Pinedo, Lying and stepping behaviors around corrective or therapeutic claw trimming, JDS Communications,Volume 2, Issue 5,2021,Pages 282-288,ISSN 2666-9102, https://doi.org/10.3168/jdsc.2020-0044. - Type: Journal Articles Status: Published Year Published: 2021 Citation: P.J. Pinedo, L.S. Caixeta, E.A. Barrell, J. Velez, D. Manriquez, J. Herman, T. Holt,A randomized controlled clinical trial on the effect of acupuncture therapy in dairy cows affected by pyometra,Research in Veterinary Science,Volume 133, 2020,Pages 12-16,ISSN 0034-5288,https://doi.org/10.1016/j.rvsc.2020.08.011. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Manr&#xfffd;quez, D., J. Velez, and P.J. Pinedo. 2020. Incidence and risk factors for reproductive disorders in organic certified dairies. Journal of Dairy Science 103:1079710808. doi:10.3168/jds.2020-18592. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Phillips, H.N.; Moon, R.D.; Sorge, U.S.; Heins, B.J. Efficacy of Broilers as a Method of Face Fly (Musca autumnalis De Geer) Larva Control for Organic Dairy Production. Animals 2020, 10, 2429. https://doi.org/10.3390/ani10122429 **Progress** 09/01/19 to 08/31/20 **Outputs** Target Audience:We have reached organic dairy farmers and organic dairy industry representatives across the United States. We delivered a virtual organic field day in August 2020 at the West Central Research and Outreach Center, Morris, MN that provided information on animal health care strategies and animal welfare for dairy calves and cows. Through this

project we reached over 500 organic dairy farmers, and have worked with organic farmers through workshops, field days, and conference presentations. We have also presented research at the Virtual 2020 American Dairy Science Association Meeting and the American Societyof Animal Scinence Meeting that reached academic colleagues. We educated 3undergraduate college students through internships that focused on organic fly control and animal health at the WCROC. The project also educated and trained 2 graduate students and 1 post-doc. Changes/Problems:COVID 19 has delayed some graduate students with finishing their degrees. However, those students will be finishing those degrees this upcoming year. What opportunities for training and professional development has the project provided?The project has trained organic dairy producers on the control of animal health for organic dairy cattle. Many extension educators and organic industry representatives were informed on organic dairy management practices at field days and conferences. We have trained 3 undergraduate students on how to conduct research and outreach in an organic situation. Graduate students from Minnesota and Colorado presented research on organic animal health at the 2020 VirtualAmerican Dairy Science Association meeting and American Animal Science Socity Meeting. How have the results been disseminated to communities of interest?We continue to offer an organic dairy day at the University of Minnesota West Central Research and Outreach Center to provide farmers and other industry personnel tools to enhance animal care on organic dairy farms. During the last year, over 100 people have attended the field days at the WCROC. Over 250 people have attended presentations related to the objective research in the project. Results are also disseminated to academic and veterinary audiences through peer-reviewed publications and abstracts presented at conferences. What do you plan to do during the next reporting period to accomplish the goals?The investigators on the project will have a conference call to review the objectives and accomplishments of the project. We will continue to work collaboratively to meet the project objectives. We will continue with data analysis of all project objectives. We will finalize publications on an reproductive disorders, pyometra, and uterine health.We will finalize the oneline resources for for veterinarians and literature review ofavailable treatments of animals on organic dairy farms. Information will continue to be disseminated at workshops, conferences, field days, and scientific conferences. **Impacts** What was accomplished under these goals? The effects of teat dipping preparturient primiparous cows on postparturient udder health and subjective parlor behavior.Primiparous cows and human handlers are at risk for decreased welfare during the postparturient transition period due to increased animal stress and aversive behaviors that can jeopardize handler safety. This study investigated teat dipping preparturient primiparous cows as a method to reduce postparturient udder infections and aversive parlor behaviors over 2 calving seasons at the University of Minnesota, USA. Three weeks prior to calving, primiparous cows were randomly assigned to receive either: 1) a weekly teat dip in the parlor (n = 41) or 2) no treatment (control; n = 34). Quarter milk samples were collected and analyzed for bacteria following calving. For the first 3 days of lactation, cows were milked twice daily in a swing-9 parabone parlor and were scored by treatment-blinded handlers at each session for parlor entry ease on a 1 to 4 scale (1 = willing; 4 = requiring handler intervention) and milking ease on a 1 to 5 scale (1 = manageable and calm; 5 = unmanageable and hostile). Score maximums and milk sample means for each cow were analyzed in linear mixed models in R with fixed factors of treatment and calving season, and a random intercept for breed (6 levels). The proportion of quarters with bacteria was similar for cows in teat dip (mean ± SE; 0.64 ± 0.09) and control (0.65 ± 0.10) groups (p = 0.9). The maximum parlor entry score was similar for cows in teat dip (2.8 ± 0.2) and control (2.9 ± 0.2) groups (p = 0.7). However, the maximum milking score was 0.51 ± 0.2 greater for cows in the control group compared to the teat dip group (p = 0.04). Results from this study indicate that teat dipping primiparous cows prior to calving may alleviate aversive cow behaviors perceived by human handlers during milking procedures. The effect of outdoor stocking density and weather on the behavior of broiler chickens raised in mobile shelters on pasture.The aim of this study was to examine the behavior, and the relationship between weather and behavior, of broilers raised in mobile shelters with two stocking densities of pasture access. Fifty straight-run Freedom Rangers were used in three replicates (N = 150) at the University of Minnesota West Central Research and Outreach Center (Morris, MN) in the summer of 2018. From 4 to 11 weeks of age, birds were housed in a floorless mobile shelter divided into two equal-sized pens with daily access to pasture. Birds were allocated to one of the two pens corresponding to the treatment groups: 1) high (0.46 m2 per bird) and 2) low (2.5 m2 per bird) density outdoor pasture allowance. Ten focal birds per pen were randomly designated for behavior observations performed eight times weekly from 5 to 10 weeks of age. Counts of the number of birds outside were recorded during each observation. Behaviors were recorded continuously for 1-minute durations (Animal Behaviour Pro© app) on each focal bird. The means averaged for each observation were analyzed in linear mixed models with fixed (treatment), random (pen and replicate), and repeated (observation) effects. Models included age, heat index, solar radiation, and their interactions with treatment based on a backward stepwise selection. The temperature range recorded during the study was 7 to 32 ?C. No behavioral differences between treatments were observed. Standing decreased (P <0.05) as heat index increased. Pasture use declined (P <0.05) when heat index was greater than 26 ?C. Foraging decreased (P <0.05) and pasture use increased (P <0.05) as age increased. The results of this study indicate similar behaviors of broilers raised with two levels of pasture allowance and suggests that hot weather negatively affects the use of pasture space. Thus, providing

shade in pasture might be a method to increasing ranging in broilers. Population approach for determining behavioral thresholds associated with health status during transition. Monitoring of behavioral variables has been used to assess individual health and estrus presentation in dairy cows. The objective was to evaluate population dynamics of behavioral variables during postpartum to determine cut-off values associated with the subsequent occurrence of health events up to 21 DIM. Cows (n = 1,350) in an organic certified herd in CO, were affixed with CowManager tags (AABV, the Netherlands) for monitoring of rumination, eating, and active times (min/d). Health events were retrieved from on-farm software (PCDart, Raleigh, NC). Cows were categorized as healthy (HT) or diagnosed with at least one health event (DZ) within 21 DIM. Explanatory variables included behavioral variables summarized in 20 min intervals at 0, 1, and 2 DIM. Logistic regression and ROC curves analysis were used to calculate cutoff values maximizing sensitivity (Se, %) and specificity (Sp, %). Calving season, parity, and dystocia were included in the models as controlling variables when P < 0.1. Overall, 17.2% of the cows were in the DZ category. Increments of the behavioral variables were associated with lower odds of disease presentation. For each 20 min/d increment in rumination at 0, 1, 2 DIM the odds of DZ decreased by 0.95 (95% CI: 0.92-0.98), 0.92 (0.9-0.95), and 0.90 (0.87-0.92), respectively. For each 20 min/d increment in eating time at 0, 1, 2 DIM the odds of DZ decreased by 0.89 (0.86-0.92), 0.85 (0.82-0.89), and 0.84 (0.8-0.88), respectively. For active time, the odds of DZ decreased by 0.96 (0.93-0.99), 0.94 (0.91-0.96), 0.95 (0.92-0.98), respectively. Eating time at 1 DIM had the greatest area under curve (AUC = 0.69), followed by eating (AUC = 0.68) and rumination time (AU = 0.64) at 2 DIM. The cut-off values that optimized Se and Sp at these points were 233.5 (Se = 65; Sp = 61), 285.9 (Se = 63.2; Sp = 61.3), and 438 (Se = 61.3; Sp = 52) min/d, respectively. AUC for active time was < 0.6 and Se and Sp < 50%. This study suggests that rumination time and eating time have discriminative value at early lactation for cows at risk of health disorders and these assessment points could be used for developing targeted prophylaxis after calving. ? **Publications** - Type: Journal Articles Status: Published Year Published: 2020 Citation: R.K. Perttu, B.J. Heins, H.N. Phillips, M.I. Endres, R.D. Moon, U.S. Sorge, Short communication: Effects of mesh leggings on fly pressure and fly avoidance behaviors of pastured dairy cows,mJournal of Dairy Science, Volume 103, Issue 1, 2020, Pages 846-851,ISSN 0022-0302, https://doi.org/10.3168/jds.2019-17267. - Type: Other Status: Published Year Published: 2020 Citation: Group Feeding Calves for Dairy Production Systems. January 2020 Dairy Star - Type: Journal Articles Status: Published Year Published: 2020 Citation: G.M. Pereira, B.J. Heins, B. O\'Brien, A. McDonagh, L. Lidauer, F. Kickinger, Validation of an ear tagbased accelerometer system for detecting grazing behavior of dairy cows, Journal of Dairy Science, Volume 103, Issue 4, 2020,Pages 3529-3544, ISSN 0022-0302, https://doi.org/10.3168/jds.2019-17269. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Diego Manriquez, Ana Velasquez-Munoz, Pablo Pinedo, Case Study: Intrauterine infusion of oregano essential oils leads to carvacrol in milk of dairy cows, Applied Animal Science, Volume 36, Issue 3, 2020, Pages 335-340, ISSN 2590-2865, https://doi.org/10.15232/aas.2019-01979. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Paudyal, S., Melendez, P., Manriquez, D., Velasquez-Munoz, A., Pena, G., Roman-Muniz, I., & Pinedo, P. (2020). 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May 2020 - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: PSVIII-32 - Late-Breaking Abstract: The effect of outdoor stocking density and weather on the behavior of broiler chickens raised in mobile shelters on pasture. 2020 B.J. Heins and H.N. Phillips. 2020 ASAS Virtual Meeting Abstract. - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: B.J. Heins. Setting Your Herd up for Success: Tips in genetics, breeding, and raising youngstock. 2020 Vermont Organic Dairy Producers Day. Randolph, VT. March 11, 2020 - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: B. J. Heins and H. N. Phillips. Enhancing Livestock Health on Organic Dairy Farms. 2020 Minnesota Organic Conference, St. Cloud, MN, January 2020 **ORG Awards 2016** MappingObjective 3: Working Group MeetingObjective 4: Development and submission of integrated proposals

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