OREI Project Details

Award Year 2021

21 Research Projects

PROJECT INDEX

19. Systems-based Approach to Enhance Quality, Safety, and Shelf Life of Organic Tree Fruit in the Pacific Northwest Grant No: 2021-51300-34913

20. Finding Common Ground - Merging Tribal Life Ways with Modern Organic Agriculture Practices Grant No: 2021-51300-34898

21. Creation of Regional and Local Maize Food Systems (products Integrating Breeders, Growers, Supply Chains and End Users) Grant No: 2021-51300-34912

Challenges and Opportunities for U.s. Organic Rice

Accession No.	1026719
Project No.	ARK02727
Agency	NIFA ARK\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34910
Proposal No.	2021-02930
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Investigator(s)	Durand-Morat, A.; Nayga, RO, M.; Shade, JE, .; Mane, RA, .; Watkins, KE, BR.; Espino, LU, .

NON-TECHNICAL SUMMARY

The demand for organic rice in the U.S. exceeds domestic supply and leads to significant import competition. Organic rice in the U.S. faces a critical knowledge gap about the competitiveness and sustainability of its production practices and consumer preferences, which are the main barriers to increasing production, consumer satisfaction, and economic benefits. The long-term goal of this project is to facilitate the growth of organic rice production in the U.S. and foster the growth of the domestic market. The specific objectives of this project are (1) to identify and assess the economic impacts of the different production practices used in organic rice production in the U.S. and the barriers to expanding organic rice production, (2) to contribute to the expansion of the local demand for organic rice by improving our knowledge about consumer attitudes and valuation for organic rice attributes, and (3) to develop a multistate outreach program to disseminate the information generated by this project.We propose to use a mixed method approach that includes farmers\' focus groups and surveys, and well-received state-of-the-art consumer behavior methods, which improves the robustness of the outcomes. Project activities and results will be disseminated through multiple channels, including interactive extension tools, presentations, and journal and news-paper publications, to guarantee that we are reaching the target audience effectively.By assessing the producer and consumer attitudes toward organic rice production and consumption, and indeitifying barriers to the adoption of organic rice in the U.S., this proposal addresses OREI\'s legislative goals 2, 5, and 7

OBJECTIVES

The overarchinggoal of this project is to facilitate the growth of organic rice production in the U.S. and foster the growth of the domestic market. To achieve this, we propose to generate information about the adoption of production and marketing practices and the attitudes of consumers toward organic rice in the U.S. We will also develop a multi-state outreach program to ensure the outcomes of this project reach the relevant stakeholders and help foster sectoral growth.The specific goals of this project include:1. Identifying and assessing the economic impacts of the different production practices used in organic rice production in the U.S., and the barriers to expanding organic rice production, including perceived risks encountered by organic rice supply chain actors.2. Contributing to the expansion of the local demand for organic rice by improving the marketing strategies based on consumer attitudes and valuation for organic rice. This will lead to the development of better marketing approaches and opportunities for the U.S. organic rice industry that will increase production to serve the domestic demand in the future.3. Developing a multistate outreach program to disseminate the information generated by

this project. This outreach component will deliver the information generated by this project to the relevant stakeholders and have a real impact on the growth and sustainability prospects of the organic rice industry in the U.S.

APPROACH

We will conduct focus groups with organic rice farmers and millers to inquire about crop management practices, marketing arrangements, production outcomes, socioeconomic conditions, production costs and receipts, and marketing costs. Specifically, we will assess the current management and economic situation of the organic rice supply chain, including the current adoption of organic rice production practices (e.g., cultural, biological, and mechanical practices), and crop management practices. We will also conduct cost-benefit analysis of the key value-chain stakeholders (e.g., millers, wholesalers, and retailers) to ascertain the distributions of benefits and risks throughout the supply chain. Organic rice production uses a variety of inputs and management approaches (e.g., green and animal manures, conservation tillage, and water seeding) that can lead to significant variations in rice enterprise budgets relative to conventional rice. We will follow the protocol used by the Agricultural & Food Policy Center (AFPC) at Texas A&M University to generate the Representative Farms, a database of agricultural operations representing the major agricultural production regions of the country. We will also use the Agricultural Resource Management (ARMS) Phase II and Phase III surveys as a reference to develop the focus group protocols.We will conduct four focus groups, two in California and two in Texas, the two largest organic rice-producing states in the U.S. The focus groups will include at least six members, four rice farmers and two millers. To make sure that participants represent the industry closely, we will seek advice from the advisory board, extension agents and industry representatives on the selection of participants.We will administer a survey of U.S. rice farmers (both organic and conventional farms) to assess their attitudes toward organic rice production practices, the regulatory system for organic certification, and the working of public programs aimed at adopting conservation practices. Based on these results, we will estimate an econometric model to analyze producers\' adoption decisions. In this model, the dependent variable would represent the probability that the event (e.g. adoption of organic practices) will occur given the selected independent variables. The usefulness of this model for policy purposes lies in the selected independent variables, whose information will come from the survey. We will involve the advisory board in the development of the survey questions to ensure the relevance of the information gathered (e.g., variables selected can have an application in the design of strategies to improve the adoption of organic farming).We will conduct choice experiments to assess U.S. consumers\' valuation for organic rice attributes. This method will be employed in five different regions of the U.S. to assess differences in consumer preferences and valuations across the regions. We will survey 300 consumers from each of the selected regional markets for a total of 1,500 consumers nationwide. We will rely on the services of survey companies such as SSI® and Research Now® to draw a representative sample of consumers and implement the online survey. The CE will test the following five attributes: production method (organic versus conventional), place of primary production, place of processing, type of sales outlet and price.The CE study will provide us estimates of consumers\' valuation for the different attributes (and the combination of these attributes) of interest (e.g., organic labeling, effect of information about origin of organic rice) by region. The findings will not only help us estimate WTP for organic rice but also assess how valuations for organic rice can be influenced by socioeconomic variables, which will help design better, more targeted, marketing strategies.We propose to develop a multistate outreach program to disseminate the findings of this project to the target audience, that is, members of the U.S. organic rice supply chain, from input suppliers to retailers, and the general organic industry. The outreach plan has five components:1. Inclusion of organic rice into the agendas of the rice field days organized by the extension services in the leading rice-producing states, including Arkansas, California, and Texas in 2022, 2023, and 2024.2. Organization of an organic rice symposium at the 2022 and 2024 Rice Technical Working Group (RTWG) Meeting. RTWG meets at least biennially to provide for continuous exchange of information, cooperative planning, and periodic review of all phases of rice research and extension being carried on by the states, federal government, and cooperating agencies.3. Participation in industry and professional conferences and meetings to disseminate information about organic rice, including that generated by this project. We propose to have a stand and potentially organize a section at the Rice Market and Technology Convention (RMTC) in 2023 or 2024 to disseminate the findings of our study and more generally update the audience about organic rice.4. Publication of interactive applications developed during the project tenure (e.g., interactive organic rice budgets and representative organic rice farm models) in the University of Arkansas Cooperative Extension Service webpage, websites of The Organic Center (TOC), and University of California Cooperative Extension.5. Collaborating with TOC to make use of their vast network of organic stakeholders, and expand our research communication efforts to a national level. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Thethirdyear\'s target audience was organic and conventional rice farmers.In the project\'s thirdyear, we conducted a rice producersurvey to ascertain (1) the return and cost structure of organic versus conventional rice, (2) organic farmers\' opinions about organic rice production, their main challengesand benefits, including

their view on current agricultural policies such as commodity title programs and crop insurance, (3) conventional rice farmers\' perceptions about organic rice production, and (4) socioeconomic characteristics of organic and conventional rice farmers. The online producer survey was launched in the second year, but the success rate was very low. In year three we changed the strategy and hired a group of enumerators to conduct phone calls and texting. We built a rice producer\'s phone directory from different sources, amounting to more than 4,000 phone contacts. We invested three months and conducted over 6,000 phone calls in total. In total, 141 surveys were completed, of which only 13 came from organic rice farmers. Moreover, because participants had the option of not answering specific questions, many chose not to answer key parts of the survey despite the enumerators\' prompting. Changes/Problems:Unfortunately, despite our efforts, we were unable to collect the target number (300) of producer surveys that would have allowed us to conduct a thorough econometric analysis of the drivers of organic rice adoption. This was an important part of our project, and the research team feels disappointed that we were not able to deliver it. Because of the challengediscussed above, we are doubling our effort to ascertain producers\' perceptions through the use of focus groups. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest?We shared our focus group findings with participants, which included organic rice farmers and millers. We presented a paper about consumer preferences for organic rice at the Western Agricultural Economic Association meeting in San Francisco. What do you plan to do during the next reporting period to accomplish the goals?In the last year of the project, we plan to: Conduct one last round of producer focus groups to share our findings with participants and gather information that will help us finish building the representative farm models. Finish building the representative farm models and organic rice budgets Conduct another online consumer survey to better understand the driver of consumer preferences for organic rice using the Means-End-Chain approach. Conduct a Webinar series and prepare online materials to present and discuss the findings of the project among organic stakeholders Impacts What was accomplished under these goals? We conducted a producer survey to support goal 1 (Identifying and assessing the economic impacts of the different production practices used in organic rice production in the U.S., and the barriers to expanding organic rice production, including perceived risks encountered by organic rice supply chain actors). Unfortunately, due to the sparsity of the data (respondents chose not to answer important parts of the survey), we cannot conduct an econometric analysis of the drivers of organic rice adoption. We are analyzing the data to see what valuable information can be retrieved from it. Also, we are finalizing the organic representative farm models, which will support goal 1. We are planning to conduct a last round of focus groups in year four to conclude our field activities. We have two papers under review looking at consumer preferences for organic rice. Publications Progress 09/01/22 to 08/31/23 Outputs Target Audience:In the project\'s second year, we conducted one focus groupwith organic rice farmers and millers to inquire about crop management practices, marketing arrangements, production outcomes, production costs and receipts, and marketing costs. We also launched the rice producer survey aimed at estimating the drivers of adoption of organic rice production. We also conducted a consumer survey to understand US consumer preferences when it comes to choosing the rice they eat. That said, this secondyear\'s target audience was organic rice farmers and millers, and US consumers. We shared the preliminary results from the focus group activities with participating farmers and millers to get their feedback before preparing the enterprise budgets and representative farm models. We also engaged a group of rice farmers in testing our producer survey to ensure it is clear and succinct. Changes/Problems:One of the major challenges we faced in year 2 was the lack of response to our online producer survey. We advertised the survey in prominent places (e.g., rice field agendas), but unfortunately, we got very few completed responses. We spent significant resources developing a phone survey, which we expect will yield the target number of 300 completed responses. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest?Preliminary results from the focus groups with organic rice farmers were shared with participants to get their feedback as we develop the enterprise budgets and farm models. What do you plan to do during the next reporting period to accomplish the goals?In the third year, we plan to conduct the producer survey. We hired 5 enumerators, whoareundergoing training. Furthermore, we are developing all the material to launch the phone survey in January of 2024. We will complete building the organic rice enterprise budgets and representative farm models. We will complete the analysis of the consumer survey already conducted in the Fall of 2023, and conduct another consumer survey to assess more deeply the preferences for choosing organic rice. We expect to present the findings of this project in different venues such as rice field days and rice conferences. Impacts What was accomplished under these goals? In the second year of the proejct we accomplished the following: In goal 1, we conducted another round of focus groups, and are in the process of building the enterprise budgets and representative farm models. The producer survey is going to be re-launched by phone in the Winter of 2024, which will provide valuable information to finalize the budgets and farm models. In goal 2, we conducted a survey of a representative sample of 1000 US consumers to find out more about their rice consumption habits and rice consumption preferences. We are processing the data and preparing a draft for a peer-reviewed publication. We are developing the material for another consumer survey aimed at knowing in more detail their motivations for choosing organic rice. In goal 3,

we keep updating our project\'swebpage (https://organic-center.org/site/challenges-and-opportunities-us-organic-rice). We are also working of a number of venues where we will present the results of this study. We are in talks with the organizers of the Rice Marketing and Technology Convention to have a space in their annual conference. We are also seeking to get into the rice field agendas in Arkansas, Texas, and California to disseminate our findings. Publications **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:In the first year of the project, we conducted two focus groups with organic rice farmers and millers to inquire about crop management practices, marketing arrangements, production outcomes, production costs and receipts, and marketing costs. The marketing conditions in 2022 are characterized by high input costs, which may result in changes in management practices relative to a more normal year. For that reason, we decided to split the focus groups into 2022 and 2023. Next year we will conduct at least two more focus group activities to complete the proposed activities under objective 1.1. With that said, the target audience this first year was primarily organic rice farmers and millers. We shared the preliminary results with participating farmers and millers to get their feedback in preparation for our second round of focus groups in 2023. The feedback we received from them was overwelmingly positive. Changes/Problems:The 2022 market situation, characterized primarily by very high input prices, led us to change our activities for year 1. The original plan was to conduct all focus groups in year 1, but given the market conditions we decided that it would be better to split these activities out into year 2 to hopefully ameliorate the potential impact of high input prices on organic rice farming activities. We hope the market conditions go back to a more normal state next year so we can conclude the focus group activities and generate the expected output. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest?We have not released any informaiton to the public yet, but shared the preliminary findings from our focus groups with the aprticipants to get their feedback before publishing the information. What do you plan to do during the next reporting period to accomplish the goals?Year two will be the most intensive in terms of activities. We plan to conduct the two remaining (but hopefully more) focus groups and build the organic rice budgets and representative farm models. We also expect to finish developing the survey protocol and launch the producer survey, and at least conduct preliminary analysis of the results. We also plan to finish the consumer survey protocols, launch the surveys, and conduct the preliminary analysis of the results. Finally, we expect to keep updating the public about all these activities through the project website. **Impacts** What was accomplished under these goals? The activities this first year were centered on goal 1. In particular, we conducted two focus groups with organic rice farmers and millers in Texas and California. While the target was to conduct the four focus groups in year 1, we decided to split them into 2 years to mitigatethe potential impact of high input prices in 2022 that could lead to changes in management practices. We developed preliminary budgets for organic rice, and are writing a working paper to report the main production and economic characteristics of organic rice production in Texas and California. Looking forward, we have already scheduled to conduct a focus group in El Campo, Texas, in January 2023, and are already planning to schedule another focus group in California in the Summer of 2023.Also related to goal 1, we aredeveloping the producer survey that will be deployed in Spring-Summer 2023. Related to goal 3, we started promoting the project through the creation of a webpage (https://organic-center.org/site/challenges-and-opportunities-us-organic-rice) to keep the public informed about the progress of this project. Regarding goal 2, we also started developing the consumer survey protocols and expect to launch thesurveys in the Fall of 2023. **Publications**

↑ Return to Index

Collaborative Knowledge Networks for Planning Organic Agriculture Research and Extension in California

Accession No.	1026773
Project No.	CA-R-ENT-5234-CG
Agency	NIFA CALB\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34916
Proposal No.	2021-02968
Start Date	01 SEP 2021
Term Date	31 AUG 2022
Grant Amount	$49,440
Grant Year	2021
Investigator(s)	Wilson, H.; Lubell, MA, N..; Muramoto, JO, .

NON-TECHNICAL SUMMARY

The development and expansion of organic agriculture in the United States has strong historical roots in California, which today accounts for the largest share of organic acres, farms and total crop value. As markets for organic food continue to expand, California organic growers and other stakeholders have expressed a critical need for additional research and training opportunities to help scale up and improve the efficiency of organic cropping systems. In response, the University of California (UC) recently created the Organic Agriculture Institute (UC OAI) to facilitate the development of research and extension programs for organic agriculture in California. This planning proposal will support efforts of the UC OAI to identify and build partnerships with a wide range of organic agriculture stakeholders to form the California Organic Agriculture Knowledge Network (Cal OAK Network). The UC OAI will then convene the Cal OAK Network around specific crop groups that includes tree nuts, tree fruit, raisins, and rice. During these meetings, a series of surveys, discussions, and focus groups will be used to identify and prioritize specific critical needs for each crop group, as well as characterize connections within each of these agricultural innovation networks. These efforts will be complimented by a series of in-depth stakeholder interviews as well. Using this information, the UC OAI will then work with the Cal OAK Network to create relevant training opportunities and develop new collaborative proposals with a high likelihood of success that will be submitted to the NIFA Organic Agriculture Research and Extension Initiative program.

OBJECTIVES

This planning proposal will allow the University of California (UC) Organic Agriculture Institute (OAI) to build partnerships with organic growers and other organic agriculture stakeholders, which includes consultants, organic certifiers, state agencies, non-governmental organizations and commodity boards. The UC OAI will partner with these stakeholders to form the California Organic Agriculture Knowledge Network (Cal OAK Network), which will provide a new platform to facilitate communication and coordination of activities amongst organic agriculture stakeholders. The UC OAI will then work with this network to identify critical research and extension needs, and use that information to collaboratively develop new training opportunities and OREI research proposals that address critical stakeholder needs for organic agriculture.

APPROACH

Objective 1 - Establish the California Organic Agriculture Knowledge NetworkKey Personnel and Timeline - Wilson, Muramoto, Lubell (9/1/21 - 10/31/21)Activities/Methods - Identify and Build Partnerships with StakeholdersThe UC OAI will identify and partner with relevant organizations, experts, and growers throughout the California food system who are involved with organic agriculture. This includes organic growers, private consultants, certifiers and producer groups (e.g. CCOF, CAFF, EcoFarm etc.), input suppliers (e.g. Rincon-Vitova, True Organic, Marrone etc.), public agencies (e.g. NRCS, CDFA etc.), non-governmental organizations (e.g. OFRF, Rodale, The Organic Center etc.), UC Cooperative Extension, and of course academic faculty and programs within the UC and other university systems (e.g. Cal. State University, Stanford etc.). These partnerships will culminate in the formation of a new entity known as the California Organic Agriculture Knowledge Network (Cal OAK Network). The UC OAI will subsequently work with the Cal OAK Network to identify research and extension needs, develop training opportunities and promote organic agriculture. Objective 2 - Identify and Prioritize Organic Agriculture Research and Extension Needs Key Personnel and Timeline - Wilson, Muramoto, Lubell (11/1/21 - 5/31/22)Activities/Methods - Stakeholder Meetings, Surveys and InterviewsA series of extension meetings will be scheduled between Nov. 2021 - May 2022 to convene members of the Cal OAK Network involved in the production of tree nuts, tree fruit, raisins and rice. There will be more than one meeting for certain crops that are grown in multiple regions, and singular meetings will take place in the primary production region. As such, there will be four meetings that separately target (#1) tree nuts/fruits and (#2) rice in the Sacramento Valley, and (#3) tree nuts/fruits and (#4) raisins in the San Joaquin Valley. Project co-PDs will work closely with the Cal OAK Network to recruit participants in a way that maximizes diversity, equity and inclusion of attendees.Each meeting will be one full day in length. Morning activities will consist of presentations on organic agriculture with emphasis on focal crop(s), followed by panel-discussions, stakeholder survey sessions and small-group discussions. There will be a group lunch and then in the afternoon a field tour to visit 1-2 regional organic farms and/or processing facilities.Stakeholder surveys will be administered using the Qualtrics online survey platform that allows for both multiple-choice and open-ended responses. The survey link can be accessed via smartphones, in real time. We will also consider implementing the survey with Turning Point software using tablets, but we believe that most OAK Network members will have compatible smartphones. While survey questions will aim to identify key technical production constraints for the focal crops (specific pests, diseases etc.), stakeholders will also be asked to identify and weigh the importance of these barriers relative to marketing, policy and other non-agronomic challenges. Surveys will also include social network questions that ask participants to describe the frequency and type of organic agriculture educational activities they currently engage in, as well as to list growers or outreach professionals with whom they communicate and/or share knowledge. Surveys will also gather baseline demographic data on number of acres managed (growers only, via a branching question structure in the survey), education level, age, years of experience and gross annual income.Discussions and surveys at the stakeholder meetings will be complimented by a series of semi-structured interviews with individual growers or consultants from each of the 10 target UC OAI crops, which includes tree nuts (almond, pistachio, walnut), tree fruit (peach, nectarine, prune, cherry, fig), raisins and rice. A total of 20 interviews will take place (10 crops x 2 stakeholders/crop = 20 interviews), and these will be conducted prior to the extension meetings in order to help better frame meeting discussions and content. Each interview will be recorded and transcribed for later analysis. Grower interviewees will be identified and selected based on years of experience farming organically, with ideally one new and one experienced grower for each pair of interviews. Data Analysis - Stakeholder Meetings and InterviewsPrior to implementation, all survey and interview protocols will be submitted for approval to the UC Riverside Institutional Review Board - Socio-Behavioral (IRB-SB). Survey responses will be anonymous and discussion/interview data remain confidential (see \"Data Management Plan\"). During each meeting, the co-PDs will note and summarize the key points from the presentations, panel discussion, small-group sessions and field tours. Survey responses will be tallied for each question, and in some cases cross-tabulated against responses to other key questions. Open-ended survey questions and interview data will be coded and summarized. All survey, discussion and interview data will then be collectively summarized for each crop type.Objective 3 - Develop New Research and Extension Proposals for the NIFA OREI ProgramKey Personnel and Timeline - Wilson, Muramoto, Lubell (6/1/22 - 8/31/22)Activities/Methods - Develop New Collaborative Research and Extension ProjectsIn some cases, it may be possible to satisfy training needs by tailoring existing information to organic growers, while in many other instances the knowledge gaps will likely require research to develop new information. Using the final report from Objective 2 as a guiding document, the UC OAI will work with the Cal OAK Network to identify relevant partnerships and collaborative teams that can best address the most pressing critical needs in each of the four focal crop groups (i.e. tree nuts, tree fruit, raisins and rice). This will likely result in a series of public/private research and extension partnerships that include some combination of UC faculty and Cooperative Extension personnel, organic growers, private consultants, NGOs and public agencies. All of these new projects will be coordinated by the UC OAI. Progress 09/01/23 to 08/31/24 Outputs Target Audience:The goals of the project were for the newly formed University of California Organic Agriculture Institute (UC OAI) to identify key stakeholders in organic agriculture throughout California and assess their needs. During this reporting period, the relevant stakeholders that we continued to engage included

producers of various organic commodities across major commodity groups like tree fruit, stone fruit, tree nuts, citrus, grapes, berries, vegetables, and livestock; actors downstream in the value chain such as handlers and processors; regulators such as organic certifiers, state agencies, non-profit organizations; technical advisory services such as Pest Control Advisors (PCAs), Crop Consultant Advisors (CCAs), and agricultural extension advisors; researchers including those affiliated with the University of California and independent research organizations. This engagement took place through regional visits, field days and discussion panels at outreach events. Changes/Problems:We encountered relatively few challenges during this reporting period. In summarizing the survey data, we did realize that more information was needed on the grower knowledge networks. While our initial survey effort did help identify key sources of information that growers rely upon, which allows us to start mapping out the knowledge network, we feel that an additional survey effort will be needed to fully flesh this out. As such, we anticipate development of a new proposal to support this work that will be submitted to the USDA NIFA OREI program in 2025. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest?As mentioned, key findings from the statewide needs assessment have been summarized in a 3-page brief/executive summary that was released in February 2024 which reviewed the key findings in the main report and is also available on the OAI website. Research participants, both those who participated in the interviews as well as the online survey, were given the opportunity to receive research findings upon completion of the project via email. Links to the report have been emailed to all those who indicated interest. These key findings were also presented at two grower meetings. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Summary and Public Presentation of Key Findings from the Statewide Needs Assessment During the reporting period, key findings from the statewide needs assessment were summarized into a 3-page document that was shared widely with key stakeholders through conference presentations and field days, as well as on the UC Organic Agriculture Institute website (https://ucanr.edu/sites/organic/Resources_107/Statewide_Needs_Assessment/). Results of the survey efforts fell into two broad categories: grower/production challenges and systemwide challenges. Grower-level challenges refers to the production (e.g., pests or crop nutrition) and non-production challenges (e.g., certification, water) that organic producers face, typically at the farm level. These in turn vary by cropping systems; farm scale (small versus medium and large farms); and farm type (i.e. fully organic, mixed conventional, or transitioning). Identification of needs by stakeholder demographic will permit the OAI to develop more targeted advisory offerings and recommend research priorities for the university and funding agencies based on these differences. Common challenges that growers reported are difficulties with weed management, pest pressures, water, labor, and costs of transition. Some other production challenges such as the availability of organic seed and stock do not occur at the farm level but are system-level issues, which we address in the next sub-point. Systemic challenges are more complicated challenges that affect multiple stakeholder groups and arise as a result of the interplay between various economic, regulatory, and environmental conditions in the sector. System-level issues are harder to address. They require policy interventions and institutional coordination; the OAI thus recommends future activities and research that will help elucidate these processes. Prioritization of Future Research Priorities Our summary of the needs assessment includes recommendations for future research funding by grantmaking agencies, faculty endowments, and recruitment within the university and agricultural extension. For instance, some recurring needs identified by participants include a need for organic research that examines farm dynamics using system approaches, organic varietal development, soil health research, need for better market demand and price projections. Furthermore, participants emphasized the need for more easily accessible technical advisory services and participatory research. The UC Organic Agriculture Institute is now using this information to develop targeted programmatic actvities to address these needs. Publications Type: Websites Status: Published Year Published: 2024 Citation: Rangarajan, S., Lubell, M., Muramoto, J., Wilson, H. 2024. A statewide needs assessment of organic agriculture in California. https://ucanr.edu/sites/organic/Resources_107/Statewide_Needs_Assessment/ Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Rangarajan, S., Lubell, M., Muramoto, J., Wilson, H. 2023. Update on the UC OAI statewide needs assessment - key findings to date. Organic Grower Summit (Monterey, CA) 11/29/23 Progress 09/01/21 to 08/31/24 Outputs Target Audience:The goals of the project were for the newly formed University of California Organic Agriculture Institute (UC OAI) to identify key stakeholders in organic agriculture throughout California and assess their needs. Target stakeholders included producers of various organic commodities across major commodity groups like tree fruit, stone fruit, tree nuts, citrus, grapes, berries, vegetables, and livestock; actors downstream in the value chain such as handlers and processors; regulators such as organic certifiers, state agencies, non-profit organizations; technical advisory services such as Pest Control Advisors (PCAs), Crop Consultant Advisors (CCAs), and agricultural extension advisors; researchers including those affiliated with the University of California and independent research organizations. Overall, insights were gathered from 426 organic producers who responded to an online survey, 65 stakeholders who responded to questions on challenges they faced in their role as well as aspirations for the industry, and 5

field trips which covered major organic zones in the state. The latter were combined with workshops on organic best practices conducted by extension advisors within University of California Cooperative Extension. Engaging with these stakeholders permitted the research team to achieve the following: An understanding of the needs and challenges felt by stakeholders of different types throughout the organic agriculture sector. Communicating these to both internal and external organizations will help identify priorities for research and extension and determine the future activities of the OAI. Through the activities conducted as part of the needs assessment, the OAI team was able to build partnerships with different stakeholders and set the stage for the development of the California Organic Agriculture Knowledge (CalOAK) Network which is intended as a clearinghouse of individuals and organizations who are contributing knowledge resources to organic agriculture, and who can be connected to each other to build knowledge capacity in the sector. Changes/Problems:A few of the challenges we encountered in the project include delays in the project due to recruitment challenges, difficulties with reaching some of our target audience, and the need for more work in identifying the full scope of the CalOAK network. Recruitment challenges: Initiation of the project was delayed due to difficulties with recruiting a postdoctoral researcher to lead the needs assessment for the first year. Due to these delays, we sought a no-cost extension of the project, after which work was completed successfully. Challenges with reaching some of the target audience: The initial planning proposal was to conduct a needs assessment of specific organic producer groups. However, in the early stages of the project, we realized that the challenges faced in the industry extended beyond the grower. Many challenges that we heard were systemic and resulted from an interplay of differing stakeholder priorities, market, environmental, and regulatory challenges. To address this, we expanded the scope of our target audience to beyond simply producer groups. We included other types of stakeholders identified under \'Target Audience\' such as input suppliers, handlers, regulators and researchers. However, despite our best efforts, not all stakeholder groups could be easily reached. The biggest gap is in understanding the needs of buyers in the market, particularly large retailers and distributors who consolidated produce. Many of the largest organic buyers have complicated administrative structures for organic purchasing and operate at a national level (as opposed to state or local). We instead attempted to partially address this gap by speaking to people who sold to these buyers to understand their perspective. More work needed on identifying the CalOAK network: Our research and extension activities have made significant progress in identifying key stakeholders who constitute the major informational resources in California\'s organic sector and is a part of an ongoing effort at the OAI. Nonetheless, our research suggests that different stakeholders have different knowledge networks which vary by the scale of operation, the region they work in, their organic ideologies and so on. For instance, larger and more profitable growers might be better able to invest in private technical advisory to address production challenges, while smaller growers might rely more on internet searches and their local grower networks. Moreover, organic being such a small part of agriculture means that people and their associated knowledge networks are more diffuse. In other words, different people access information differently which might impact the potential success of technical advisory services. We have some preliminary insights on these patterns from our research which we would like to expand upon in the future. A new survey instrument that we have developed attempts to explicitly identify these knowledge networks. Implementing it is however beyond the scope of this planning proposal; we hope to implement it with future research funding. What opportunities for training and professional development has the project provided?The project provided training opportunities for the organic community as well as research team members. Workshops on organic practices on topics such as soil health, nitrogen management, cover cropping, and organic regulation was supported by the OAI. The audience for these workshops were mainly growers but also included other people in the organic community. These workshops and field days also provided a networking opportunity for growers in the community to interact with each other. Internally, the project provided professional development opportunities for early-career project members. The postdoctoral researcher on the project was given authorship on research papers and reports that stemmed from this research, opportunities to present at leading academic and farmer conferences, opportunity to interface with relevant industry members, and mentorship on developing these study protocols and outputs. An undergraduate researcher also worked with the postdoc for two academic quarters on research fundamentals, data organization, and some qualitative coding. How have the results been disseminated to communities of interest? Research reports to the organic community: Research findings from the needs assessment have been compiled in a final report that is available on the UC OAI website, titled \'A statewide needs assessment of organic agriculture in California\'. This was preceded by a 3-page brief/executive summary that was released in February 2024 that reviewed the key findings in the main report and is also available on the OAI website. Research participants, both those who participated in the interviews as well as the online survey, were given the opportunity to receive research findings upon completion of the project. Links to the report have been emailed to all those who indicated interest. This report also documents future research priorities and funding needs that stakeholders identified, which is relevant to researchers and funding institutions. Journal articles: Research articles developed from the research will be submitted to peer-reviewed journals that are geared towards the academic and policy communities. These articles identify specific research and policy goals that can be the subject of future work. Conference presentations: As outlined in the previous section, research findings have also been presented at 2 academic and

2 farmer conferences, the latter of which . What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Formation of the CalOAK network The CalOAK network is intended as a stakeholder network where people can reach each other to facilitate knowledge exchange and share resources. People who opt-in to participation are part of our research, communications, trainings, and future activities. We used multiple approaches to recruit people to this network. First, Project Director Wilson\'s network was used as the starting point for identification of key stakeholders who are well known in the industry for contributing knowledge or spearheading policies and industry initiatives. These people in turn were asked to identify other key players, some of whom were interviewed. Every person surveyed is given the opportunity to add themselves to any future mailing lists or resource networks that the OAI develops. Second, we received lists of growers and handlers registered with the CDFA SOP. Growers were emailed an online survey, one question of which allows them to opt into future communications. These efforts have initiated the formation of the CalOAK network which we expect will grow over the next few years as institute events and participation increases. Needs assessment and roadmap for the OAI: The needs assessment identified the most urgent challenges and needs in the organic sector for different stakeholders. These were organized into two categories: Grower-level challenges which refers to the production (e.g., pests or crop nutrition) and non-production challenges (e.g., certification, water) that organic producers face, typically at the farm level. These in turn vary by cropping systems; farm scale (small versus medium and large farms); and farm type (i.e. fully organic, mixed conventional, or transitioning). Identification of needs by stakeholder demographic will permit the OAI to develop more targeted advisory offerings and recommend research priorities for the university and funding agencies based on these differences. Common challenges that growers reported are difficulties with weed management, pest pressures, water, labor, and costs of transition. Some other production challenges such as the availability of organic seed and stock do not occur at the farm level but are system-level issues, which we address in the next sub-point. Systemic challenges are more complicated challenges that affect multiple stakeholder groups and arise as a result of the interplay between various economic, regulatory, and environmental conditions in the sector. System-level issues are harder to address. They require policy interventions and institutional coordination; the OAI thus recommends future activities and research that will help elucidate these processes. Identifying future research priorities: Another key goal of the needs assessment was to identify research priorities for agricultural researchers and extension advisors at the University of California and beyond. It also recommends areas for future research funding by grantmaking agencies, faculty endowments, and recruitment within the university and agricultural extension. For instance, some recurring needs identified by participants include a need for organic research that examines farm dynamics using system approaches, organic varietal development, soil health research, need for better market demand and price projections. Furthermore, participants emphasized the need for more easily accessible technical advisory services and participatory research. Publications Type: Journal Articles Status: Other Year Published: 2024 Citation: Rangarajan, S., Lubell, M., Lloyd, M., Wilson, H. \"Policy contradictions in organic farming in California: Findings from a California-wide needs assessment\" (in preparation) Type: Journal Articles Status: Other Year Published: 2024 Citation: Rangarajan, S., Lubell, M., Wilson, H. \"Farm size and type influence organic production and non-production challenges\" (in preparation) Type: Other Status: Published Year Published: 2024 Citation: Rangarajan, S., Lubell, M., Muramoto, J., Wilson, H. \"Challenges in Organic Agriculture in California: Summary of findings from a statewide needs assessment\" https://ucanr.edu/sites/organic/files/396228.pdf Progress 09/01/22 to 08/31/23 Outputs Target Audience:We continue to conduct our statewide needs assessment for organic agriculture. While this primarily focuses on certified and transitioning organic farmers, we are also interviewing and/or surveying consultants, pest control advisors, processors, input vendors, marketing and retail in order to capture a more contextual understanding of the challenges and needs of the organic community. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?As mentioned, we are starting to create an online resource database for organic farmers, written documents that summarize key issues and resourcesc, as well as organize in-person training events. We already held a field day on organic rice on 7/26/23 (Yuba Cita, CA), and are scheduled to host additional field days later this year on organic vegetable production (Arcata, CA), citrus and berry production (Ventura, CA) and soil management / grazing in vineyards (Santa Rosa, CA). How have the results been disseminated to communities of interest?So far no results have been disseminated since we are still conducting and/or analyzing the survey work. What do you plan to do during the next reporting period to accomplish the goals?Over the next reporting period we plan to conclude all survey work and then summarize/analyze those datasets. From that, we will generate publications for peer-review scientific journals, industry press, a one-page summary for our website, as well as a series of presentations and posters that will be used to present findings back to the organic community. Impacts What was accomplished under these goals? We recruited a new postdoctoral scholar (Dr. Shriya Rangarajan), who started working on this needs assessment in Sept. 2022. Over the fall 2022, we developed (1) a quantitative online survey and (2) a qualitative survey that uses a semi-structured interview. Both of these were focused on characterizing the key challenges and needs of organic farmers, along with capturing basic demongraphic data on farmer type, experience, scale of production etc. Survey recruitment began in January 2023. The quantitative survey received

\>350 respondents and we have conducted \>40 interviews. The quantitative survey is now closed and we are evaluating the data, while we will continue to conduct interviews for about 6 more weeks. While the results of the statewide needs assessment will drive numerous programmatic activities within the UC OAI, we are already starting to take action on some preliminary findings. For instance, many organic farmers have told us that while resources for organic agriculture are generally limited, those resources that do exist are difficult to find and navigate. As such, we have started to create documents that will posted to our website (http://organic.ucanr.edu/) to help with this navigation issue. For instance, we are currently working on a document that summarizes and provides details about the various organic farmer training programs in California. We have also started to develop the Cal OAK Network more broadly. The first step has been to develop an online resource database that is linked to a publically available mapping tool. Farmers and other relevant parties can indicate where they are located and the map will provide a list of all relevant technical, financial and social assistance programs/personnel/organizations that are focused on organic agriculture. This will also soon include a network of organic demonstration sites and mentors, through a partnership with California Certified Organic Farmers (CCOF). We are also now in the process of organizing field events for organic farmers. Our first field day took place on 7/26/23 and was focused on organic rice production Publications **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: Nothing Reported Changes/Problems: Work on this project was initially delayed and so a no-cost extension was requested with a new end-date of 8/31/23. The delay is because a postdoctoral scholar was recruited and hired in the fall of 2021, but this employee resigned after 3 months because she was offered a faculty position elsewhere. As such, we reinitiated the recruitment process over the winter 2022 period. While we were able to find a new postdoctoral scholar to work on this project, this new employee did not start work until September 2022. 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? Nothing Reported **Impacts** What was accomplished under these goals? Nothing to report.

↑ Return to Index

Organic Sweet Potato Ipm and Soil Health Management for Small- and Mid-size Farms

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Performing Institution	UNIV OF HAWAII, 3190 MAILE WAY, HONOLULU, HAWAII 96822

NON-TECHNICAL SUMMARY

The overall goal of this project is to present guidelines for small- to mid-size organic sweetpotato farmers. We aim to develop an economical IPM against sweetpotato weevil, nematodes and soil-borne diseases, while restoring soil health. The project will be conducted in Hawaii and Alabama as this information is especially lacking here but we anticipate the outcomes to have broad applications in other regions. Specific objectives are to: 1) develop organic IPM strategies against sweetpotato weevils using pheromone traps, entomopathogenic nematodes, and Beauveria bassiana through proper spray nozzles; 2) prescribe soil health management strategies compatible with small- and mid-size farms through small-farm equipment, cover crops with allelopathic effects against plant-parasitic nematodes, and fertigation with biological nematicides (ArmourZen®, Majestene®); 3) deduce the relationship between soil microbial profiles associated with the suppression of soil-borne pathogens; 4) estimate the economic return of soil health management and organic IPM approaches for sweetpotato farmers, and 5) broadly transfer knowledge gained through online platforms besides face-to-face extension (decision making apps for phones, new farmers training programs, social media, virtual conferences, college students etc.). A multidisciplinary team of 7 scientists/extension personnel in Hawaii plan to work with at least three commercial organically certified sweetpotato growers in Hawaii and 7 extension agents/specialists/professors from Alabama with expertise in Plant Pathology, Entomology, Horticulture, and Ag Economics. We received strong support from new farmers training programs in Hawaii and Alabama, as well as from the Associate Dean of Research at Auburn University who is initiating an Organic Initiative Demonstration Farm in Alabama.

OBJECTIVES

The overall goal of this project is to present a decision support tool for small- to mid-size organic sweetpotato farmers that can lead to an economical integrated pest management against sweetpotato weevil, nematodes and soil-borne diseases, while restoring soil health through cover cropping. We choose to develop this project in Hawaii and Alabama as this information is especially lacking here but anticipate that the concept will be applicable to other regions. It is also our goal to broadly transfer our knowledge gained through online platforms besides face-to-face extension. Specific objectives to achieve this goal are to:1) develop organic IPM strategies

against sweet potato weevils using pheromone traps, entomopathogenic nematodes, and Beauveria bassiana through proper spray nozzles;2) prescribe soil health management strategies compatible with small- and mid-size farms through small-farm equipment, cover crops with allelopathic effects against plant-parasitic nematodes, and fertigation with biological nematicides (ArmourZen®, Majestene®);3) deduce the relationship between soil microbial profiles associated with the suppression of soil-borne pathogens;4) Estimate the economic return of various soil health management and organic IPM approaches for sweetpotato farmers; and5) Broadly transfer knowledge gained through online platforms besides face-to-face extension (decision making apps for phone, new farmers training programs, social media, virtual conferences etc.)

APPROACH

Objective 1. Develop organic IPM strategies against SPWObjective 1a (EPN application rates): In Hawaii, a field experiment will be established to determine field inoculation densities for optimal EPN rates once the economic threshold of 4 weevils/pheromone monitoring trap per week is reached on \'Okinawan\' sweetpotato using H. indica mix with an organic surfactants such as Oroboost (Oro Agri, USA) using a modified backpack sprayer with drop nozzles of air induction dual pattern (ADPF) flat spray tips. Each treatment will be replicated in 4 plots, arranged in randomized complete block design. Experiment will be repeated once. Sweetpotato weevil (SPW) population will be baited with a ground trap every 2 weeks till harvest. Root damage at harvest from each plot will be evaluated by randomly selecting eight roots and counting the number of feeding pin holes caused by SPW per tuber root. These 8 tubers will be immersed in individual water tubs and quantify the SPW adults or larva emerged after 24 hours. If cadavers are found, they will be incubated on individual White Traps to determine EPN infection rates. Marketable and unmarketable tuber weight will be recorded and weighted. Similar field trials will be conducted at Brewton and Tallassee in Alabama but using commercial EPN, Heterorhabditis bacteriophora (Larvanem®, Koppert Biological System).Objective 1b. Integrating male pheromone traps with EPN and EPF: Field trials will be conducted at Waimanalo and Lihue in Hawaii; Brewton, Tallassee in Alabama and Dobson in North Carolina. Each farm will dedicate 4 distant sweetpotato fields for 1) male lure only; 2) male lure + EPN release; 3) male lure + EPN release + entomopathogenic fungi (EPF) Beauveria bassiana spray, and 4) an untreated control. Pheromone trap will be placed at the beginning and at 4 months after planting, installed in the center of the field using Pherocon unitraps at plant height. SPW will be monitored using ground traps. Infection rates of EPN and EPF will be monitored using the modified White Trap. Sweetpotato damage and yield will be monitored Each location trial will be repeated at least once.Objective 1c. Spray nozzles to increase efficacy of biopesticides: A short experiment will be set up towards harvesting time of a sweetpotato crop where three types of nozzle tips will be compared: 1) Turbo air induction dual pattern (ADPF) flat spray tips, 2) Turbo TeeJet Induction (TTI) nozzle, and 3) most commonly used flat fan nozzle tips. Two biopesticides, Heterorhabditis indica and B. basiana (Mycotol®) will be tested against SPW and for sweet potato yield response.Objective 2. Prescribe soil health management strategies compatible with small- and mid-size farms (conservation tillage, cover cropping and fertigation).Objective 2a. Cover crop Test. Field trials will be conducted in Hawaii and Alabama. The cover crops to be tested include black oat, oil radish, \'Tropic Sun\' sunn hemp, \'512×14\' sorghum-sudangrass hybrid and \'NX-D-61\' energy sorghum in a strip-till system using a flail mower and narrow tine tiller. Slips of sweet potato will be planted. Dry biomass of cover crop will be determined. Soil samples will be systematically sampled at the termination of cover crop prior to flail mowing, and at 2-month intervals after sweetpotato planting. Soil properties from each field trial will be examined for extractable P, NO3- nitrogen, soil organic matter, cation exchange capacity (CEC), pH, soil bulk densities and field capacity. In addition, a soil penetrometer will be used as an assessment tool for farmers to monitor soil compaction. Volumetric and gravimetric soil moisture will be recorded at each soil sampling event. Nematodes will be extracted from a 250-cm3 subsample and identified to genus, counted, and subjected to nematode community analysis to calculate trophic group abundance, richness, Simpson\'s index of diversity, enrichment index (EI), structure index (SI), and channel index (CI).Marketable and unmarketable yield of sweetpotato will be weighed and monitored and recorded for incidence of Java black rot, soft rot, Ceratocystis black rot, nematode damage (root cracking) and sweetpotato weevil damage.Objective 2b. Post plant biological nematicides: Each cover crop main plot in Obj 2a will be split into post-plant fertigation treatments: 1) ArmourZen (Botry-Zen, Ltd.), 2) Majestene (Marrone Bio Innovations) and 3) water control administered at monthly intervals. Plant-parasitic nematodes extracted from each subplot at 2-month intervals will be compared.Objective 3. Deduce the relationship between soil health and soil-borne disease suppression.Soil samples from the root zone of each cover crop established in Objective 2a will be collected at cover crop termination, 28 and 84 days after sweetpotato planting and subjected to phospholipid fatty acid (PLFA) assay (Microbial ID, Inc., Newark, Delaware). PLFA can resolve the microbial community into 6 groups: Gram positive bacteria, Gram negative bacteria, Actinomycetes, Non-AM fungi, AM fungi, and Protozoa and provides their phospholipid fatty acid biomass per nmoleg. Soil microbial respiration will also be estimated using Solvita gel test (Solvita and Woodend Laboratory).Objective 4. Estimate the economic return of various soil health management and organic IPM approaches for sweetpotato farmers.Cost analysis will be conducted at each participating farm

individually using a partial budgeting framework method to evaluate costs and benefits of non-chemical based SPW management relative to conventional pesticide based and/or long-term crop rotation practices, as well as the no-treatment control. Our cost analysis will mainly be focusing on the treatment activities and their associated costs which are different from the conventional control. Benefits will be measured in terms of crop yield and quality with their associated prices, plus amount of pesticide use reduction. For costs, data will be collected for numbers of application, labor requirements, and cost of the associated materials. This analysis will estimate the breakeven price, i.e., the maximum amount that growers could pay per unit of the non-chemical IPM methods for results to be comparable to the conventional practices or untreated control. At that price, the grower will be indifferent between using the non-chemical based IPM or the conventional treatment. Since 3 consecutive trials will be conducted at each site, cost analysis changes over time will reflect the progressive benefits of non-chemical based IPM for SPW management.Objective 5. Transfer knowledge through online platforms and face-to-face extension.Detail on online outreach are listed in the Product section. Workshops or videos will be made to educate farmers how to rear EPNs using meal worms in Hawaii. Specific educational workshops / extension publication include:1) DIY EPN rearing techniques and step-by-step EPN inoculation in the field;2) Biological control and spray improvement strategies against sweetpotato weevils;3) Cover cropping for nematodes, soil-borne diseases and soil health management for sweetpotato farmers;4) Cost and Benefits of organic IPM practices for sweetpotato farmers; and5) New Organic Sweetpotato Production Guidelines to increase production of sweetpotato.We will bring awareness to the farmers that SPW is not the only concern for sweetpotato production, so are other pests including plant-parasitic nematodes, rough sweetpotato weevils, sweetpotato whiteflies, Bemisia tabaci, black rot, soft rot and even weeds etc. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Sweet potato farmers in Alabama, Hawaii and North Carolina (particularly organic farmers, but some conventional farmers also will seek for non-chemical approach being recommended from our project). New Farmers training programs (e.g. GoFarm Hawaii in 5 locations in Hawaii- Waialua and Waimanalo on Oahu, Hilo on Hawaii Island, Lihue on Kauai Island, Maui). New farmers enrolled in Alabama Beginning Farmer\'s program Beginning farmers interested to grow sweet potato seeking for effective and reduced risk pest management approaches (many of these farmers in Hawaii are immigrant farmers from Asia including Vietnam, Laos, Thailand, China, and the Philippines). Changes/Problems:It is encouraging to see that when we prepare local isolate of Metarhizium anisopliae into a compost and amended into soil at planting, number of sweet potato weevil larvae recovered from sweet potato at harvest was significantly reduced. This is a breakthrough from our last year report when using EPN or commercial EPF. None-the-less, we hope to further improve organic IPM approaches that can combine soil health enhancement with the use of pheromone baits against SPW, B. bassiana spray along with M. anisopliae compost mix and cover cropping to reduce nematode pest pressure to achieve sweet potato yield improvement. We encounter more serious pest issues (three weevil species and a stem borer) on sweet potato production in Hawaii than we first anticipated (SPW) in Hawaii. In terms of EPN, we have identified more virulent strains of Hawaiian isolates of EPN and hope to improve the effects of EPN in the field. Efforts to formulate these EPNs into desiccated waxworm cadaver is also in progress to improve survival of EPN in the field. While we consistently see the benefits of cover cropping when integrated with various biopesticides used in all three states (AL, HI, NC) for soil health and crop yield improvement, the needs of small-scale sweet potato farmers to use potato harvester attached to a BCS tractor remained a problem to maneuver in the high clay soil in Hawaii. We hope to overcome this soil disturbance from sweet potato harvesting and soil hilling through the use of cover crops with higher biomass production to replenish C lost, e.g. using high biomass cover crops like sunn hemp, sorghum and velvet bean. Performance of biopesticides worked better in the field with better soil health (e.g. in North Carolina field trials) but not well in the field trials conducted in Alabama in our study. This affirm that soil health management needs to go hand in hand with IPM. What opportunities for training and professional development has the project provided?Univ. Hawaii: A total of 2 M.S. students graduated from the University of Hawaii at Manoa working on this project, whereas a Ph.D. student is continuing a longer-term evaluation of soil health. The Ph.D. student won multiple best student awards from the College of Tropical Agriculture and Human Resilience (CTAHR), University of Hawaii while presenting his results. He also secured a new graduate student grant from WSARE to expand on organic sweet potato IPM development. Four undergraduate students were hired to assist with various aspects of this project. An undergraduate student presented this study and won the best student paper at the CTAHR Student Research Symposium, Undergraduate Research Opportunity Program (UROP) at the University of Hawaii, as well as a travel award to attend the Society of Nematologists meeting. A Ph.D. student from Osaka University came to the University of Hawaii as an exchange student and worked on additional organic IPM approaches for sweetpotato with the PI(Total of 8 students). Auburn University: A graduate student has recently graduated from Auburn University. A postdoctoral researcher is being hired to continue the data analysis of this study. Four conference papers were presented at various scientific conferences by the graduate student this year. Two undergraduate students were hired to assist with this project (Total of 3 students and a postdoc). How have the results been disseminated to communities of interest?Univ. Hawaii: In between 2023 Aug to 2024 Aug 2024, a total of 3 in person workshops (2 on Oahu and one on Hawaii islands), one webinar for Kauai sweet potato farmers, and 5 guest lectures for

GoFarm Hawaii New Farmers\' Trainingprogram (distributed on Oahu, Kauai, Hawaii and Maui islands) were offered by PIs and a graduate student to share our findings from this OREI project besides general cover crop, IPM and soil health management approaches to farmers throughout Hawaii. Auburn University: Between Aug 2023 to Aug 2024, a total of 3 field days were offered to farmers at Smith Research Center and Gulf Coast Research and Extension Center in Alabama, and at Tennessee Valley Research and Extension Center by PI Lawrence and Graham. PI Graham also broadcast an interview with all students and PIs who worked on this OREI project on his The Alabama Crops Report Podcast (https://www.aces.edu/blog/podcast/season-3-episode-11-aloha-from-alabama-extension). PI Wang also highlight this OREI project in 2024 Multistate Research Fund Impacts. https://www.mrfimpacts.org/single-post/sustainable-nematode-management. A total of 11 Conference oral or poster presentations were presented by the students working on this project, and two invited symposia talks were presented by PI Wang and PI Sipes this year. What do you plan to do during the next reporting period to accomplish the goals?We plan to improve organic IPM strategies against SPW based on the research data we gathered so far. We will continue to analyze the data from soil health analysis to depict the relationships between soil health indicators with sweet potato yield and pest suppression. We will evaluate farmers perspective on \"Prescription of soil health through cover cropping for organic sweet potato production\" Provide partial economic analysis of the Organic IPM approaches for sweet potato production developed in HI and AL. Complete all peer-reviewed publications associated with these projects. Impacts What was accomplished under these goals? Obj 1. Develop organic IPM Strategies Entomopathogenic nematode (EPN): Through 5 laboratory trials, susceptibility of sweetpotato weevil (SPW, Cylas formicarius) larvae to 3 indigenous EPN isolated from Hawaii: Steinernema feltiae MG-14, Oscheius tipulae OA-12, and Heterorhabditis indica OM-160 were evaluated. S. feltiae was most promising, causing SPW mortality of 50%, whereas O. tipulae and H. indica caused 30% and 25% SPW mortality, respectively. Subsequently, the efficacy of S. feltiae was tested as basal stem sprayed at monthly intervals beginning at swollen root formation in 2 sweetpotato field trials. However, result was inconclusive due to low pressure of SPW (\< 1 weevil/kg root at harvest). Another field experiment was conducted at a commercial sweetpotato farm with high SPW pressure using EPN (O. tipulae). Three treatments tested were 1) O. tipulae monthly basal stem spray (from 2 -5 months after planting), 2) untreated control, and 3) grower carbaryl monthly foliar spray. Although sweetpotato treated with O. tipulae did not reduce SPW damage compared to grower practice, it reduced SPW than the untreated control (P \< 0.05). Entomopathogenic Fungi: Two species of entomopathogenic fungi (EPF): Beauveria bassiana (Botanigard®) and a Hawaiian isolate of Metarhizium anisopliae \'KO-002\' were evaluated against SPW in the lab and the field. In laboratory petri dish trials, SPW larvae exposed to Botanigard® resulted in 30% larvae mortality. In a series of olfactometer tests, M. anisopliae \'KO-002\' did not attract or repel SPW adults. In a greenhouse trial, amending soil with \'KO-002\' enhanced sweetpotato growth. In 2 field trials comparing sweet potato plants treated or not treated with Botanigard® as basal stem spray at monthly intervals when sweetpotato swollen roots started to form reduced sweetpotato weevil damage (P ≤ 0.05) but did not reduce SPW population density nor damage level compared to the untreated control (P \> 0.05). In another field trial, M. anisopliae \'KO-002\' prepared into compost and amended into the soil at planting. Though it did not affect sweetpotato yield or SPW population densities at harvest, it reduced SPW damage (P ≤ 0.05). Thus, it is promising to identify a local isolate of M. anisopliae from Hawaii as commercial biopesticides are highly regulated. Obj. 2. Prescribe soil health management strategies At the University of Hawaii: We examined 4 tropical cover crops with allelopathic effects against reniform (Rotylenchulus reniformis) or root-knot nematodes (Meloidogyne incognita) in greenhouse and field trials. In the greenhouse, we confirmed that velvet bean (VB) was as suppressive to root-knot (M. incognita) and R. reniformis as marigold (MG), sorghum (SG), and sunn hemp (SH), and VB was the only cover crop tested to reduce R. reniform nematode reproductive factor (final nematode counts/initial nematode inoculum) \< 1. Four varieties of VB with different characteristics (vine types, bush types, variegated seed coat, plain seed coat) showed equal resistance to M. incognita. Two field trials were conducted to examine the effects of MG, SG, SH, and VB as preplant cover crop vs bare ground followed by 5-months of sweetpotato planting. Velvet bean and SH suppressed reniform nematodes. This research also demonstrated that an integrated pest management strategy combining velvet bean cover cropping with the SPW pheromone trap and the monthly basal stem spray of B. bassiana during the sweetpotato root formation stage provided the most promising organic approach to managing SPW. VB was determined to be a good weed and plant-parasitic nematode suppressive cover crop with great soil health benefits. At Auburn University: A total of 4 field trials were completed, 2 in Alabama and 2 in North Carolina between 2021-2023. A split-plot experiment was conducted in each trial where the main plot was winter cover crop treatments, and the subplot was biopesticides combination vs no biopesticide for management of Meloidogyne incognita and insect pests. At the Alabama field trials, field pea increased M. incognita population densities, but increased sweet potato yield at harvest. In North Carolina, mix cover cropping of wheat, crimson clover, daikon radish, and Elbon rye significantly reduced the number of root-knot nematodes while improving sweet potato yield. The effects of a biopesticide combination (EPN, EPF with Mycotrol, and Majestene as bionematicides) on sweet potato yield were unclear. However, we did observe a trend of soil health effects influencing the performance of biopesticides. Obj 3. Deduce the relationship between soil health and pathogen

suppression Univ. Hawaii: Soil physical (water infiltration, aggregate stability, soil moisture), chemical (C and NH4-N) and biological (microbial soil respiration, microbial phospho-lipid amino acid, PLFA, and nematode community indices) were monitored throughout the two field trials conducted in Hawaii. In Trial I, planting velvet bean prior to sweet potato was most promising tropical cover crop because velvet bean: 1) was most water efficient in generating biomass compared to the other 3 cover crops; 2) increased total soil C and soil labile amonia-nitrogen (SLAN) more efficient than the other cover crop within one cropping cycle; 3) fostered a more diverse and less stressful soil community as evidenced by increased soil microbial diversity, gram negative (G-) bacteria, total fungi, arbuscular mycorrhizal fungi (AMF) biomass, and fungi: bacteria ratio, while reducing actinomycete (ACT) microbial biomass; and 4) reduced the proliferation of plant-parasitic nematodes in the soil during the sweet potato growing season; and most importantly, 5) reduced the damage of sweet potato tuberous roots from rough sweet potato weevils and increased the colonization of soil insects by indigenous entomopathogenic fungi such as B. bassiana and M. anisopliae. After repeating the same treatments of cover crops for the second year (Trial II), VB and sorghum (SG) increased G-, AMF, total fungal biomass but only VB increased abundance of bacterivorous nematodes compared to BG (P \< 0.05). When all parameters were subjected to Canonical Correspondence Analysis (CCA), different results were observed in Trial I vs II. In Trial I, VB was segregated from BG and all other cover crops in the CCA scatter plot (first two Canonical axes=70.86% variation). Abundance of reniform and root-knot nematodes were negatively related to structure index (SI), indicated a more structured soil food web dominated by omnivorous and predatory nematodes would lead to less plant-parasitic nematodes. However, sweetpotato yield was not affected by all soil health parameters. Progressing to Trial II following soil disruption from sweetpotato harvesting and bed formation, CCA depicted a strong negative relationship between root-knot nematode abundance with channel index (CI), but population densities of reniform nematodes crashed in all treatments and showed no relationship with any soil health parameters. Sweetpotato yield again did not show relationships with any soil health parameters (first 2 canonical axes=81.75% variation). No segregation among treatments at the end of Trial II. We speculate that a suppressive soil against reniform nematodes might have developed after an outbreak of reniform nematodes in Trial I. Auburn University: Soil microbial respiration and microbial biomass were being monitored in all field trials in AL and NC. Progress is being made to depict how changes in soil microbial profile could lead to better performance of biopesticides and lead to better suppression of plant-parasitic nematodes. These results were presented at the Society of Nematologists meeting in Aug 2024. More data analysis will be performed to summarize the results. Publications Type: Theses/Dissertations Status: Published Year Published: 2023 Citation: Wong, L. 2023. Management of the sweet potato weevil (Cylas formicarius) using pheromone traps, entomopathogenic fungi, and entomopathogenic nematodes. M.S. Thesis, University of Hawaii at Manoa, Honolulu, HI. 154 pp (https://scholarspace.manoa.hawaii.edu/server/api/core/bitstreams/b2e1b3f2-cb44-444d-85e7-bfe78001955e/content). Type: Theses/Dissertations Status: Published Year Published: 2024 Citation: Schloemer, C. 2024. Evaluation of winter cover crops and biological control products to manage Meloidogyne incognita and insect pest damage in organic sweetpotatoes. M.S. Thesis, Auburn University, Auburn, AL. 107 pp (https://etd.auburn.edu/bitstream/handle/10415/9143/Schloemer_Thesis_Final.pdf?sequence=2) Type: Journal Articles Status: Published Year Published: 2024 Citation: Pitiki, M., R. Paudel, J. Mew, and K.-H. Wang. 2024. Examining susceptibility of white clover, buckwheat, black oat and forage radish as a long-term cover crop mix to Meloidogyne incognita. Nematropica 54: 41-48 (https://journals.flvc.org/nematropica/article/view/135613). Type: Journal Articles Status: Submitted Year Published: 2024 Citation: Schloemer, C. M., Graham, Scott H., and Lawrence, Kathy S. Sweetpotato pest challenges and management options. Journal of Integrated Pest Management (Submitted May 2024). Type: Other Status: Published Year Published: 2024 Citation: Wong, L., K.-H. Wang and B.S. Sipes. 2024. Benefits of an entomopathogenic fungus, Metarhizium, for enhancing sweetpotato growth and sweetpotato weevil suppression. H?nai?Ai 54: June 2024. 6 pp. https://gms.ctahr.hawaii.edu/gs/handler/getmedia.ashx?moid=73341&dt=3&g=12. Type: Other Status: Published Year Published: 2023 Citation: Schloemer, C.M. S.H. Graham, K.S. Lawrence. 2023. Greenhouse evaluation of winter cover crops to manage Meloidogyne incognita on sweetpotato, 2023. Plant Disease Management Reports 17: N056. The American Phytopathological Society, St. Paul, MN. https://www.plantmanagementnetwork.org/pub/trial/pdmr/reports/2023/N056.pdf Type: Other Status: Published Year Published: 2023 Citation: Schloemer, C.M., S.H. Graham, K.S. Lawrence. 2023. Microplot evaluation of biological control products to manage Meloidogyne incognita on sweetpotato, 2022. Plant Disease Management Reports. Plant Disease Management Reports 17: N055. The American Phytopathological Society, St. Paul, MN. https://www.plantmanagementnetwork.org/pub/trial/pdmr/reports/2023/N055.pdf Type: Other Status: Published Year Published: 2023 Citation: Schloemer, C.M., S.H. Graham, K.S. Lawrence. 2023. Efficacy of biological control products to manage Meloidogyne incognita on sweetpotato, 2022. Plant Disease Management Reports. Plant Disease Management Reports 17: N044 (PDMR Volume 17 - Efficacy of biological control products to manage Meloidogyne incognita on sweetpotato, 2022 (plantmanagementnetwork.org) Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Wong, L., K.-H Wang, B. S. Sipes. 2024. Organic approaches to manage sweet potato weevil (Cylas formicarius) using entomopathogenic nematodes and

entomopathogenic fungi in Hawaii. Society of Nematologists 63rd Annual Conference, Aug 4-9, 2024, Park City, UT. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Larger, K., R. Paudel, B. Wiseman, and K.-H. Wang. 2024. Determining host susceptibility of cover crops to reniform nematodes. Society of Nematologists 63rd Annual Conference, Aug 4-9, 2024, Park City, UT Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Wiseman, B., M. Pitiki and K.-H. Wang. 2024. Model-mania! Exploring differences in soil health management between four tropical cover crops in a sweetpotato agroecosystem. Society of Nematologists 63rd Annual Conference, Aug 4-9, 2024, Park City, UT. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Nicco P. Silvester and B. S. Sipes. 2024. 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Multistate Research Fund Impacts. https://www.mrfimpacts.org/single-post/sustainable-nematode-management. Progress 09/01/22 to 08/31/23 Outputs Target Audience:Sweet potato farmers in Alabama, Hawaii and North Carolina (particularly organic farmers, but some conventional farmers also will seek for non-chemical approach being recommended from our project). New Farmers training programs (e.g. GoFarm Hawaii in 4 locations in Hawaii- Waialua and Waimanalo on Oahu, Hilo on Hawaii Island, Lihue on Kauai Island). New farmers enrolled in Alabama Beginning Farmer\'s program Beginning farmers interested to grow sweet potato seeking for effective and reduced risk pest management approaches (many of these farmers in Hawaii are immigrant farmers from Asia including Vietnam, Laos, Thailand, China, and the Philippines). General farmers interested to use cover crop for soil health management - these farmers are reaching out to the PI to get advice on \"Prescription of Soil Health Management using Cover Crop\" (\> 40 phone calls or e-mails to the PI during this project period referred from a cover crop seed distributor in Hawaii). Farmers participated in two of our field day/Workshop events: 1) Poamoho Cover Crop Field Day; 2) Sustainable Nematode Management for row crops. Pacific Islander NRCS Conservationists that visited our field site at Poamoho Subscribers of Hanai\'Ai, an online newsletter for local farmers in Hawaii Cover crop seed distributors (Kooloa Seed and Supplies, Petcher Seess etc) Oahu Resource

Conservation and Development (RC&D) Council, Classroom instruction for an undergraduate program \"Sustainable Plant and Soil Health Management (PEPS 410)\" - to learn about cover crop for soil health management with lab section in the field to monitor soil health (soil infiltration, microbial respiration, soil compaction, aggregate stability, soil moisture, nematodes as soil health indicators). Experiential learning experience for five graduate students participate in this project to learn about nematode identification, soil health analysis, rearing entomopathogenic nematodes, growing a varieties of cover crops, and sweet potato cultivation. Another 8 undergraduate students were hired to assist in various aspects of data collection from the fields and laboratories. Changes/Problems:Although we see an improvement in marketable yield of sweet potato when combining entomopathogenic nematodes (EPN) and fungi (EPF) application with winter cover cropping in the Alabama and North Carolina trials, there is a lack of efficacy in field application of entomopathogenic nematodes (EPN) against key insect pests of sweet potato in Hawaii. Three weevils and a stem borer were major pests of concern in Hawaii, and our under canopy foliar spray of EPN did not suppress these pests in our 2021-2022 field trial and did not improve crop yield. This is anticipated in part because commercial EPN products were not available in Hawaii, and we had to rely on locally isolated and reared EPNs. We have identified more virulent strains of Hawaiian isolates of EPN and hope to improve the effects of EPN in the field. Efforts to formulate these EPN into desiccated waxworm cadaver is also in progress to improve survival of EPN in the field. While we consistently see the benefits of cover cropping when integrated with various biopesticides used in all three states (AL, HI, NC) for soil health and crop yield improvement, the needs of small-scale sweet potato farmers to use potato harvester attached to a BCS tractor remained a problem to maneuver. This is particularly challenging in high clay soil and no-till plots (without bed formation). We plan to test this harvester again in more sandy soil and form raised beds for sweet potato planting. This will allow us to perform better economic analysis of small-scale sweet potato production in Hawaii. Most sweet potato farmers in AL and NC are mid-size farms and are not challenged by this problem. What opportunities for training and professional development has the project provided?Four graduate students at University of Hawaii (UH), one graduate student at Auburn University (AU), 8 undergraduate assistants (4 from AU and 4 from UH) have been employed or trained to conduct research for this project. The project provides training opportunities for students not limited to the field of Nematology, Entomology, Plant Pathology and Soil Sciences. A total of two society awards were gained by the graduate students presenting at national conferences. Other professional development opportunities provided include new farmers\' training programs in Hawaii through GoFarm Hawaii and Alabama Beginning Farmer\'s program. Guest lectures were presented to new farmers periodically and allowed us to share our findings from this OREI project with the farmers. PI Wang also works closely with conservation planners from Oahu Resource Conservation and Development (RC&D) Council to develop online training materials for Hawaii\'s Woman Farmers Network. This year we translated a training material about cover crops used into Chinese language to reach out to Chinese immigrant farmers. How have the results been disseminated to communities of interest?Objective 5: Outreach Using this result from velvet bean and the PI\'s former accumulated data from other tropical cover crops, we generated a chart on \"Prescription for Soil Health by Cover Cropping for Hawai\'I\" (https://gms.ctahr.hawaii.edu/gs/handler/getmedia.ashx?moid=72134&dt=3&g=12) and submitted toHanai\'Ai Newslettervol 50 for Hawaii agriculture practicians. We migrate ourCover Crop Calculator appto a permanent site to assist farmers in decision making on how much nitrogen fertilizer to cut back from growing cover crops. This is a Cover Crop Calculator to calculate plant available nitrogen from different cover crops based on biomass and N content from an established cover crop. Co-PI Silva had been presenting how to use this app to farmers through various outreach events. Users can access this on their cell phone, an improved version from an excel sheet that one needed to download from our website before. Co-PI, Graham interviewed PIs and students from this OREI project and generated a podcast for the general audience, mostly reaching out to farmers in Alabama. \https://podcasts.apple.com/us/podcast/alabama-crops-report/id1557750157 \ Five guest lectures were delivered to a new farmers\' training program, GoFarm during this fiscal year. We reached out to approximately 48 participants (new organic farmers in Hawaii). These guest lectures provided new farmers an overview of cover crop selection for soil health and pest management. We emphasized pest management relevant for small-scale organic sweet potato production. New farmers now have a network to reach out to our PI and co-PIs for specific questions regarding organic sweet potato production. PI Wang and Uyeda along with other members of the Western Cover Crop Council (Hawaii Chapter) identified the top priorities of farmers interested in using cover crops being finding cover crops that are 1) drought tolerant, and 2) nematode resistant/suppressive, 3) can produce seeds locally as imported cover crop seeds some time have short shelf life. What do you plan to do during the next reporting period to accomplish the goals?For Objective 1, we will repeat all the field trials conducted so far. An olfactometer experiment will be conducted to determine if Metarhizium could repel sweet potato weevil. Using the lab studies conducted this year, we will re-explore the use of entomopathogenic nematodes against sweet potato weevils and rough sweet potato weevils in the field. In addition, we will initiate a chemigation trial using bionematicides (MeloCon® LC, Certis Biologicals) against root-knot and reniform nematodes (Objective 2). We will repeat the field trials for Objective 3 (examine the relationship between soil microbial profiles with soil-borne pathogen suppression) and Objective 4 (estimate economic return of soil health

management and organic IPM for sweet potato production) in Hawaii and Alabama. More field days and demonstration trials (Objective 5) will be conducted to fulfillreplicated trials for each study. Impacts What was accomplished under these goals? Obj. 1. Develop organic IPM strategies University of Hawaii: Three M.S. students examine various biological-based approaches 1) soil application of Entomopathogenic Nematodes (EPN) Steinernema feltiae, 2) release of EPN using lab infected mealworm cadavers (=desiccated EPN bomb), 3) mill run compost colonized by a local isolate of the entomopathogenic fungus, Metarhizium spp., 4) foliar spray of Metarhizium anisopliae (MetMaster), and 5) foliar spray of Beuavaria bassiana (Mycotrol) to manage sweet potato weevil (SPW), Cylas formicarius; West Indian sweet potato weevil, Euscepes postfasciatus; rough sweet potato weevil (RSPW), Blosyrus asellus and sweetpotato stem borer, Omphisa anastomosalis. Experiment I: The field trial at Poamoho Experiment Station examined the integration of preplant cover crops (marigold, sorghum, sunn hemp, and velvet bean vs bare ground), SPW Pherocon unitraps (Alpha Scents), and monthly foliar spray of Mycotrol. The use of SPW pheromone trap and Mycotrol reduced 80% of SPW damaged roots compared to untreated control ($P \leq 0.01$). However, most of the harvested sweet potatoes were damaged by rough sweet potato weevil (RSPW). Interestingly, velvet bean (VB) resulted in lowest RSPW damaged roots, a 53.4% reduction compared to the bare ground (BG) ($P \leq 0.05$). We monitored occurrence of B. bassiana and Metarhizium anisopliae which are entomopathogens at 1 and 2 months after sweet potato planting. Soil field cages baited with 5 waxworm (Galleria mellonella) larvae were buried 2 inches (5 cm) deep in VB and BG for 1 week, and the incidence of waxworm larvae colonization by B. bassiana (Bb) or M. anisopliae (Ma) were recorded over 2 weeks. Approximately 30% of the waxworms in VB were colonized by Bb or Ma, but no colonization was observed in BG, suggesting that VB enhanced Bb and Ma colonization in the soil. Experiment II: Metarhizium has been reported as an endophyte on several crops and enhances the growth of those plants. Preliminary results were obtained from one greenhouse sweet potato trial and one field trial at Kualoa Ranch. In the greenhouse trial, soil inoculated with an isolate of Metarhizium spp. from the Koolau mountain range increased sweet potato shoot growth by 34.5% after 2 months. In the field trial, the same isolate of Metarhizium, made into a compost mulch by inoculating the Metarhizium cultured on rice into mill run at 2 oz/60 lb, was added to sweet potato raised beds at 0.9 lb/12 ft2 plot. Plant growth at 2 months after planting were measured with noticeable plant height differences between Metarhizium amended and non-amended plots. The experiment is in progress. Experiment III: Following the outcomes from the entomopathogenic nematode (EPN) field trial at TwinBridges Farm reported last year, laboratory trials were being conducted to examine other Hawaiian isolates of EPN and their concentrations against SPW larvae in vitro. Two repeated trials with 10 replications were conducted. Steinernema feltiae MG-14 achieved 90% mortality, whereas Oscheius tipulae OA-12 only caused \<40% mortality, compared to approximately 10% mortality of SPW larvae in the no EPN control ($P \leq 0.05$). Low dosage of S. feltiae (105 infective juveniles/dish) had similar mortality of SPW larvae as the high dosage (525/dish). Another Hawaiian isolate of EPN, Heterorhabditis indica OM-160 achieved 70% mortality and did not benefit from using higher dosage. Obj. 2. Prescribe soil health management strategies. University of Hawaii: From Experiment I, where cover crops \'NX-D-61\' energy sorghum, \'Tropic Sun\' sunn hemp, velvet bean, and \'NemaGone\' marigold were grown for 3 months, terminated by strip-till before planting sweet potato. Soil samples throughout the crop were subjected to a series of soil physical and chemical property tests, microbial profile assay using phospholipid fatty acid (PLFA) analysis, and nematode community analysis as soil health indicators. VB increased soil C at 2 weeks after strip-tilling of the cover crop compared to the BG. Though not different from the other treatments, VB resulted in the highest water infiltration rate. Based on Solvita Labile Amino-Nitrogen (SLAN) test which reports organic nitrogen reserves present as amino-sugars in soil, VB increased ammonia-N in the soil compared to BG ($P \leq 0.05$), indicating a higher pool of plant available organic N. Based on PLFA analysis, VB increased soil microbial diversity, gram-negative bacteria, total fungi, arbuscular mycorrhizal fungi biomass, and fungi: bacteria ratio (F/B) ($P \leq 0.05$), but lowered actinomycete biomass ($P \leq 0.05$). All of which indicated that VB promoted a more diverse, and less stressful soil conditions. Auburn University Field Trials: An Auburn University graduate student conducted two winter cover crop field trials in Brewton, Alabama (Trial I) and Dobson, North Carolina (Trial II) for a second year. Seven cover crops tested in Brewton were crimson clover, \'Elbon\' Rye, Daikon radish, \'Koto\' buckwheat, brown mustard, field peas and black oat; whereas 4 cover crops tested in Dobson were Crimson clover, Elbon Rye, Daikon radish, wheat and a mix of Elbon rye, Crimson clover, and Daikon radish. Cover crops were planted and grew from October2022 to May 2023 and sweet potato was planted June 6, 2023 in Alabama and June 9, 2023 in North Carolina. Field peas generated the highest biomass in Trial I and elbon rye generated the highest biomass in Trial II. 30 days after planting (DAP), crimson clover plots supported the highest plant-parasitic nematode population in Trial I. The fallow plots supported the highest plant-parasitic nematode population at 30 DAP in Trial II. Both experiments are ongoing with soil health monitoring. Greenhouse tests: An Auburn University graduate student conducted two greenhouse tests of winter cover crops (Test 1) and summer cover crops (Test 2) on root-knot nematode (Meloidogyne incognita) reproduction. Winter cover crops tested included black oats, crimson clover, daikon radish, elbon rye, field peas, wheat, and yellow mustard. Summer cover crops tested included \'Pipper\' sudangrass, sunn hemp, and velvet bean. In Test 1, root-knot nematode numbers were highest on field peas

(5430 eggs/g roots) and lowest on \'Elbon\' rye (48 eggs/g root) after 56 days. In Test 2, velvet beans supported the lowest population of root-knot nematodes (18 eggs/g roots) followed by sunn hemp and sudangrass. Ob. 3: deduce the relationship between soil health and pathogens suppression Sweet potato harvested from each plot in Experiment I were subjected to postharvest storage observation after curing in a greenhouse for 1 week. Roots were stored in a plastic shoebox in a dark room for 2 months. Although a portion (27/60) of the sweet potatoes had mold growing on the surface of the roots during the storage, only 3 sweet roots remained with mold at the end of the 2-month observation. No difference was observed among treatments (P \> 0.5). Thus, we couldn\'t draw a relationship between soil microbial profiles with soil-borne pathogens on sweet potatoes. When compiling all the PLFA biomass, nematode community indices, soil physical and chemical properties, and yield in B. bassiana treated (Bb+) vs non-treated (Bb-) plots using multivariate analysis, the first 2 axes explained 86.91% of variance. Yield in Bb+ were positively related to nematode structure index, enrichment index, and richness, soil carbon content, volumetric soil moisture, water infiltration rate, arbuscular mycorrhizal fungi biomass and dry biomass of cover crops. Interestingly, yield from Bb- had negative relationships with the above parameters but was positively related to soil aggregate stability. Thus, application of Bb showed synergistic effects when used in conjunction with planting cover crops with high biomass production. Publications Type: Websites Status: Published Year Published: 2023 Citation: Cover Crop Research https://cms.ctahr.hawaii.edu/wangkh/Research-and-Extension/Cover-Crops Type: Journal Articles Status: Published Year Published: 2023 Citation: Schloemer, C.M., S.H. Graham, K.S. Lawrence. 2023. Efficacy of biological control products to manage Meloidogyne incognita on sweetpotato, 2022. Plant Disease Management Reports 17: N044. The American Phytopathological Society, St. Paul, MN. https://www.plantmanagementnetwork.org/pub/trial/pdmr/reports/2023/N044.pdf Type: Other Status: Published Year Published: 2023 Citation: Wang, K.-H., and B. S. Sipes. 2023. Prescription for soil health by cover cropping in Hawaii: for annual cropping systems. HanaiAi 50: June 2023. (https://gms.ctahr.hawaii.edu/gs/handler/getmedia.ashx?moid=72134&dt=3&g=12) Type: Other Status: Published Year Published: 2023 Citation: Schloemer, C.M., S. H. Graham, and K. S. Lawrence. 2023. Integrated management of southern root-knot nematode on sweet potato. Alabama A&M & Auburn University Extension, Alabama Cooperative Extension System. 4 pp. (https://www.aces.edu/blog/topics/crop-production/integrated-management-of-southern-root-knot-nematode-on-sweet-potato/) Type: Other Status: Published Year Published: 2023 Citation: Manandhar, R., Taiwan, G., and Wang, K.-H. 2022. Farmer Driven Sweetpotato Seevil IPM using UNI-Traps. 2023. HanaiAi 48: Newsletter December 2022. 7 pp. https://gms.ctahr.hawaii.edu/gs/handler/getmedia.ashx?moid=71762&dt=3&g=12. Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: Wang, K.-H., Paudel, R., Marquez, J., and Waisen, P. 2023. Nematode linkage to regenerative agriculture in the tropics/subtropics. Symposium How Will Regenerative Agricultural Practices Affect Parasitic Nematode Populations? Society of Nematologists 62nd Annual Conference, July 9-14, 2023, Columbus, Ohio (50 audience). 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Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2023 Citation: Pitiki, M., B. Wiseman, and K. -H. Wang. 2023. Evaluating soil health benefits of four tropical cover crops in the tropic for sweet potato production. Society of Nematologists 62nd Annual Conference, July 9-14, 2023, Columbus, Ohio. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Schloemer, C., Wang, K.-H., Sipes, B.S., Graham, S.H., and Lawrence, K.S. 2022. Evaluation of sweet potato IPM using organic methods. Joint Annual Meeting of the Entomological Society of America Vancouver, WA (student Second Place award for oral presentation). Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2023 Citation: Schloemer, C., Lawrence, K.S., Graham, S.H., Wang, K.-H., and Sipes, B.S. 2023. Winter cover crops and biological products to manage Meloidogyne incognita and promote soil health in sweetpotato. Society of Nematologists 62nd Annual Conference, July 9-14, 2023, Columbus, Ohio. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: Sweet potato farmers in Alabama, Hawaii and North Carolina (particularly organic farmers, but some conventional farmers also will seek for non-chemical approach being recommended from our project). New Farmers training programs (e.g. GoFarm Hawaii in 4 locations in Hawaii-Waialua and Waimanalo on Oahu, Hilo on Hawaii Island, Lihue on Kauai Island). New farmers enrolled in Alabama Beginning Farmer's program Beginning farmers interested to grow sweet potato seeking for effective and reduced risk pest management approaches (many of these farmers in Hawaii are immigrant farmers from Asia including Vietnam, Laos, Thailand, China, and the Philippines). General farmers interested to use cover crop

for soil health management - these farmers are reaching out to the PI to get advice on \"Prescription of Soil Health Management using Cover Crop\" (> 30 phone calls or e-mails to the PI during this project period referred from a cover crop seed distributor in Hawaii). Farmers participated in two of our field day events: 1) Poamoho Field Day; 2) Healthy Soil, Healthy Farm Field Day and Workshop at Island Harvest, Kohala. Classroom instruction for an undergraduate program \"Sustainable Plant and Soil Health Management (PEPS 410)\" - to learn about cover crop for soil health management with lab section in the field to monitor soil health (soil infiltration, microbial respiration, soil compaction, aggregate stability, soil moisture, nematodes as soil health indicators). Experiential learning experience for four graduate students participate in this project to learn about nematode identification, rearing entomopathogenic nematodes, growing a varieties of cover crops, and sweet potato cultivation. Changes/Problems: While Objective 1 is currently facing challenges in field efficacy of entomopathogenic nematodes, we will continue to rear other strains of EPN that are more virulent for field trials in Hawaii. Co-PIs in Alabama would be testing commercial strains of EPN known to be more virulent in the field. It took a long time for PI in Hawaii to purchase a small farm sweet potato harvester, but we anticipated the equipment can be shipped in the next few months. This will allow us to perform better economic analysis of small-scale sweet potato production in Hawaii. What opportunities for training and professional development has the project provided? Three graduate students at University of Hawaii (UH), one graduate student at Aurburn University (AU), 5 undergraduate assistants (4 from AU and 1 from UH), 2 post doctorate researcher in AU (worked on this project for 3 months) and a high school volunteer in Hawaii have been employed or trained to conduct research for this project. The project provides training opportunities for students or post doctorates not limited to the field of Nematology, Entomology, Plant Pathology and Soil Sciences. Other professional development opportunities provided include new farmers' training programs in Hawaii through GoFarm Hawaii and Alabama Beginning Farmer's program. Guest lectures were presented to new farmers periodically and allowing us to share our findings from this OREI project with the farmers. PI Wang also works closely with conservation planners from Oahu Resource Conservation and Development (RC&D) Council to develop online training materials for Hawaii's Woman Farmers Network. How have the results been disseminated to communities of interest? We initiated a \"New Sweetpotato Production Guidelines\" project starting from preparing a guideline for sweetpotato farmers to manage plant-parasitic nematodes organically. An infographic powerpoint entitled \"Nematode Management for Sweetpotato\" were shared with our extension agents that work with sweet potato farmers. We transferred a cover crop plant available nitrogen estimation excel sheet into an app for farmers to decide how much nitrogen fertilizer they can cut back from growing cover crops. Using this model, we will continue to develop more cover crop decision making tools / apps later. Five guest lectures were delivered to a new farmers' training program, GoFarm. We had reached out to approximately 48 participants (new organic farmers in Hawaii). These guest lectures provided new farmers an overview of cover crop selection for soil health and pest management. We emphasized on pest management relevant for small-scale organic sweet potato production. New farmers now have a network to reach out to our PI and co-PIs for specific questions regarding organic sweet potato production. PI Wang and Uyeda along with other members of the Western Cover Crop Council (Hawaii Chapter) identified the top priorities of farmers interested in using cover crops being: finding cover crops that are 1) drought tolerant, and 2) nematode resistant/suppressive, 3) can produce seeds locally as imported cover crop seeds some time have short shelf life. A post-presentation survey form from our soil health outreach activities in Summer 2022 revealed that 1) all participating farmers are very interested in growing cover crop using minimal-tillage; 2) 90% of these farmers are interested in growing short-term instead of long-term cover crops; and 3) 55% grow cover crops for soil health, and 18% for soil-borne pathogens management. What do you plan to do during the next reporting period to accomplish the goals? For Objective 1, we will explore the use of other indigenous populations of entomopathogenic nematodes and fungi against sweet potato weevils and rough sweet potato weevils. In addition, we will initiate a chemigation trial using bionematicides (ArmourZen®, Majestene®) against root-knot and reniform nematodes (Objective 2). We will initiate field trials for Objective 3 (examine the relationship between soil microbial profiles with soil-borne pathogen suppression) and Objective 4 (estimate economic return of soil health management and organic IPM) in Hawaii and Alabama. More outreach (Objective 5) will be conducted in Alabama once we completed the two cover crop field trials on-going in Alabama and North Carolina. Recently we initiated a post presentation survey for farmers to reach out to us for the \"Prescription for soil health Using Cover Crop\" program. We ask the farmers to describe soil health issues they are challenged with in their farms. We will then mail them a cover crop mix for a trial area. **Impacts** What was accomplished under these goals? Objective 1. Develop organic IPM strategies against sweetpotato weevils University of Hawaii: A field trial was conducted by a M.S. student at a commercial sweetpotato farm, Waialua, HI to evaluate efficacy of three organic approaches to manage sweetpotato weevils (SPW) on 'Okinawan' sweetpotato at Waialua on Oahu, HI. A 2×2×2 (pheromone × EPN × Beauveria) factorial designed experiment was conducted. A standard practiced (pesticide spray) was also included for comparison. Half of the field was within the efficacy zone of a Pherocon Unitrap baited with 1000 g male lure (Z3-Dodecenyl-E2-butenoate, Alpha Scents, Inc., West Linn, OR), the other half was not. Half of these plots received an indigenous entomopathogenic nematode (EPN) as foliar treatment

(185,325 infective juveniles)/ha, whereas half of them were not. For the Beauveria treatment, half of these plots received Mycotrol ESO® (Beauveria bassiana, Bioworks) at 4 fl oz/acre delivered through 20 gal/acre of water. Both EPN and Beauveria treatments were added with an organic surfactant, Kinetic® and applied above and below the leaf canopy. Unfortunately, due to culture failure of Sterinernema feltiae in the laboratory, a weaker EPN strain, Osheius tipulae, was used as foliar EPN spray in this trial, with no effect against SPW. A laboratory petri dish experiment confirmed that SPW larvae were more susceptible to S. feltiae than O. tipulae. Rough sweetpotato weevil (Blosyrus asellus) was a more dominant pest in this field than SPW and resulted in severe damage to sweet potato roots at harvest, but the larva as well as the adults of this pest remain cryptic and hard to monitor. It is speculated that Unitrap effective zone is wider than the 60 m diameter zone as suggested by the product label, as high number of SPW adults were captured in the Unitrap and overall low recovery of sweetpotato roots with SPW damage and larva in the roots sampled (< 3 per 100 g roots) regardless of close to or far from the Unitrap. None-the-less, Unitrap reduced damage scale (scale of 0-5) of combining of SPW and rough SPW but failed to increase sweet potato yield at 4 months after planting. Mycotrol® could not reduce the damage rating of SPW or rough SPW, in fact it significantly increased SPW larvae in the roots (P ≤ 0.05). Regardless of poor performance of Mycotrol and EPN foliar treatments, we were able to reisolate an indigenous EPN (putatively identified as a Heterorhabditis sp. based on18s rDNA ITS) and a fungal isolate with colony growth similar to Beauveria. Pathogenicity tests of these isolates against SPW larva or rough SPW larva remained to be tested to be relevant. Among the three approaches of IPM management tested against SPW (EPN, Beauvaria, Pheromone trap), growers are most excited about the use of Pherocon Unitrap. A total of 16 Unitraps purchased from this project had been distributed to commercial and new sweet potato farmers in Hawaii. Most of these farmers were not previously aware of using pest specific pheromone traps to control SPW. These farmers now are less worried about SPW but are asking for more organic approaches to manage rough sweetpotato weevils organically. Objective 2. Prescribe soil health management strategies A graduate student at Auburn University conducted two cover crop field trials in Brewton, Alabama (Trial I) and Dobson, North Carolina (Trial II). Seven cover crops tested in Brewton were Crimson clover, Elbon Rye, Daikon radish, Koto buckwheat, brown mustard, field peas and black oat; whereas 4 cover crops tested in Dobson were Crimson clover, Elbon Rye, Daikon radish, wheat and a mix of Elbon rye, Crimson clover, and Daikon radish. Cover crops were planted from Nov 2021 to May 2022. Sweet potato was planted Jun 15, 2022. Elbony rye generated the highest biomass at 5 months after planting, whereas Koto buckwheat and brown mustards did not survive the winter. In both locations, plant-parasitic nematodes were present at similar population levels across all cover crops at sweet potato planting and at 30 days after planting (DAP). Beneficial nematode (mostly bacterial feeders) populations were significantly higher following the Crimson clover, Elbon rye and wheat cover crops compared to the Daikon Radish. In Alabama and North Carolina, the sweet potato plots were split and untreated or treated with the biological nematicide, Majestine. Majestine increased the Normalized Difference Vegetation Index (NDVI) green rating for the sweet potato crop following the Elbon Rye. Soil health is being monitored using nematode community and microbial biomass (phospholipid fatty acid) analysis. Objective 5: Outreach (see section onHow have the results been disseminated to communities of interest). **Publications** - Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: Wong, L., K.-H. Wang, and B. S. Sipes. 2022. Infection and mortality of sweetpotato weevil (Cylas formicarius) by Hawaiian isolates of entomopathogenic nematodes, Steinernema feltiae and Oscheius sp. Society of Nematologists 61th Annual Conference, September 26-29, 2022, Anchorage, Alaska. - Type: Other Status: Published Year Published: 2022 Citation: Manandhar, R. 2022. Three promising sweet potato varieties for Kaua?i from a 2019 trial. CTHAR Cooperative Extension V46: 7 pp. (https://gms.ctahr.hawaii.edu/gs/handler/getmedia.ashx?moid =71115&dt=3&g=12).

↑ Return to Index

Carrot Improvement for Organic Agriculture: Leveraging On-farm and Below Ground Networks

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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, nutrient acquisition, nematodes, disease pressure, and weed competition 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 promote plant health and suppress pathogens; and a participatory breeding model that may be adapted to other crops for organic cultivar development. Organic farmers, students, and industry stakeholders across the US 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 and Alternaria 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

Cultivar and breeding population development and release. Expand participatory variety trial and plant breeding network. Investigate links between microbiomes, nutrient uptake, pathogen resistance, and root nutritional quality and storability among carrot genotypes Utilize molecular markers to improve nematode resistance Evaluate and improve carrot flavor, texture and color

APPROACH

Focus Area 1: Cultivar and breeding population development and release 1) Sources of germplasm and breeding approaches: At least 200 carrot breeding stocks will be preliminarily evaluated for inclusion in the CIOA3 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.2) Field evaluation for foliar and seedborne diseases: Visual evaluations for foliar carrot diseases will be performed on all researcher managed trials in all four years of the project to score resistance levels in breeding lines.3) Project managed trials: Research station locations represent diverse environments in commercial carrot production areas for large- and small- scale growers in the respective regions of the San Joaquin Valley of CA, the Columbia Basin of WA, and maritime climate of Western WA.4) Preliminary breeding and selection: At least 75 populations will advance throughout CIOA3, 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.5) 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). Stock seed will be increased on collaborating organic seed farms in WA, released to organic seed companies in Years 2-4, and promoted through outreach, participatory trials, and culinary evaluation activities.6) Public domain release and protection of new cultivars: McCluskey and Hubbard will lead the building and launch of the new Plant Prior Art Repository (PPAR) online database and development of educational materials about how to utilize the GRIN system for variety trialing and plant breeding work. CIOA3 populations and finished cultivars will be added to the PPAR with Simon\'s direction and shared widely with the Extension, research, and farming communities across the US. Targeted education and outreach will be conducted, including to Extension agents, public breeders. Focus Area 2: Expand participatory variety trialing and plant breeding network. Participatory on-farm networks: 1) Network expansion: At least 10 organic farmers and smaller scale organic seed companies will partner with the breeding team to advance populations on-farm, and commercialize new varieties and at least 40 farms per year will participate in decentralized on-farm variety trials nationally.1) Participatory Plant Breeding (PPB): Organic Seed Commons is a digital platform hosted by OSA that provides intuitive networking among users based on interest, skillset, and geography, and robust delivery of dynamic online education.2) Participatory variety trials: SeedLinked will serve as the platform for coordinating decentralized on-farm variety trials to test advanced breeding lines and new cultivars. Focus Area 3: Investigate links between microbiomes, nutrient uptake, pathogen resistance, and root nutritional quality and storability among carrot genotypes. In the first study, four carrot cultivars that vary in potential resistance to A. dauci, including two that differed in responsiveness to beneficial microbes with suppressive activity against A. dauci in our previous studies (Napoli and Red Core Chantenay), will be grown in five diverse environments (CA, WA, IN, VT, VI).In the second study to evaluate whether carrot cultivars release chemically distinct root exudates that recruit specific strains of rhizosphere bacteria and fungi, which together can result in differences in carrot growth and quality, field trials will be conducted on the certified organic field plots at West Madison Agricultural Research Station (WMARS) as well as a parallel greenhouse trial at UW-Madison.1) Cultivar recruitment of rhizosphere microorganisms: To evaluate whether carrot cultivars release chemically distinct root exudates that recruit specific strains of rhizosphere bacteria and fungi, which together lead to differences in their nutrient uptake and growth differs, trials 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).2) Field trial methods: Carrots will be harvested 120 days after planting. Assessments will include carrot sugar and carotenoid concentrations via high performance liquid chromatography, and carrot top weight, root weight, and root length.3) On-farm testing of rhizosphere associations: The work proposed will include on-farm studies providing data and further input from organic farmers, which will further enhance our overall understanding of rhizosphere dynamics in organic systems across two soil systems.4) Root exudate methods: Root exudates will be collected in a manner similar to Hao et al. (2010) and Herz et al. (2018). Briefly, after removal of rhizosphere soil roots will be washed with running tap water and then with deionized water three times.5) Post-harvest quality: Storage is extremely important to organic growers as carrots are a reliable source of income during the winter months6) Flavor evaluation: Assessment of carrot flavor will be integrated into all germplasm evaluations and breeding activities. Focus Area 4: Utilize molecular markers to improve nematode resistance1) Nematode resistance analyses: CIOA2 entries will be screened for resistance to M. javanica, M. incognita, and M. hapla each year. Infested field sites containing each species separately at University of California research stations in Parlier, Irvine, and Thermal, and the WSU Othello Research Farm will be used.2) Development and application of gene markers: Total genomic DNA will be isolated from freeze-dried leaves, and GBS-derived SNP markers for the suite of nematode multi-species resistance QTL identified by the project team (Parsons et al., 2015). Focus Area 5: Evaluate and improve carrot flavor, texture and color 1) Selection for carrot flavor and texture: Initial organoleptic evaluation of the trial entries by PD Simon 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).2) Evaluation and selection for root color: Visual evaluation for intensity of color of all pigment classes will be performed on all carrot roots selected

as breeding material in Focus Area 1. Initial selection in the field will be judged on exterior color.3) Analysis of carrot pigments: Advanced breeding populations grown at DREC, Hancock, and OSA trials, and selected participatory trials will be evaluated in the Simon Lab for nutritional pigments. Progress 09/01/23 to 08/31/24 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: Nothing Reported What opportunities for training and professional development has the project provided?The CIOA team advises carrot breeding and variety evaluation for small to medium scale seed companies and carrot farmers engaged in on-farm breeding. We also advise our colleagues at the Univ. of British Columbia enabling a growing network of CA on-farm carrot breeding activities. The project provides access to diverse genetics along with trainings to skill-up participants delivered through eOrganic and the Organic Seed Commons. These efforts are expanding the number of independent carrot breeders developing varieties for diverse climatic and market needs. As part of education activities, undergraduate students, graduate students, and post-doctorates are also 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, and present in professional conferences. Kayla Quintero (MS student at Purdue) investigating carrot genotype by microbiome by plant disease - received additional training, advanced experiments, and is continuing field trialing, data collection and analysis. Clare Talamy and Hannah Anderson (MS students at Univ. of Wisconsin-Madison) are investigating parallel field and greenhouse studies exploring whether the composition and functional potential of the carrot rhizosphere microbiome is governed by the chemical composition of root exudates. Avelina Gaston (MS student at UW-Madison) is receiving training for developing machine methodologies for testing carrot texture and for investigating the genetics of carrot root texture. Extension activities included creating new project promotion and educational materials for CIOA3, coordinating outreach and evaluation activities, presenting at multiple scientific and food industry conferences, and delivering trainings and educational events. Trials were conducted with organic seed company research farms. 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. Susana Cabrera-Mariz, Iowa State University, collaborated with CIOA to conduct research on carrot history, domestication, and cultural food pathways as a component of her MS thesis (2024 graduation). 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 to disseminate research updates, timely articles, and related project events (http://eorganic.info/carrotimprovement). 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. Project collaborators hosted public farmer field days in conjunction with trials at the project research sites. Field days coincided with timing of trial evaluations. How have the results been disseminated to communities of interest?Educational events and conference presentations delivered include: Webinars: 3/22/24. Unearthing the flavors of CANOVI-CIOA carrot trials and farm breeding club. https://seedalliance.org/2024/canovi-cioa-carrot-trials-webinar/ Field Days and Trainings: 3/5/24 field day for industry carrot breeders and production personnel to evaluate breeding materials from the project and from industry sources for agronomic performance and trialing of selected CIOA entries in comparison to available cultivars, El Centro, CA 5/14/24, Conventional carrot variety trial, Bakersfield, CA, University of California Cooperative Extension. 8/21/24 field day for industry carrot breeders and production personnel to evaluate breeding materials from the project and from industry sources for root-knot nematode resistance and agronomic performance, Coachella, CA 8/26/24 OSA Washington Researcher Field Day 9/13/24 West Madison Field Day, Madison, WI. Outreach activities presented on this project by the University of California, Desert Research and Extension Center, Holtville, CA: From 2023 to 2024 Farm Smart delivered carrot outreach programs in nutrition and production to over 2500 participants, which includes educators, K-12 students, and community members. Below is a summary of activities delivered: Farm to Summer - Carrots Led an interactive summer program where participants learned about the history of carrots, nutritional information, how they grow, and tasted a variety of carrot preparations, including the various colors. CARES Fall Festival- carrot planting Participants learned about carrots as they planted their own carrot seeds to take home Farm Tours- carrot presentation, research, harvesting While touring the facility, guests learned about colored carrot research taking place at the farm. Farm to Preschool Festival- carrot tasting and facts Participants tasted carrots and received recipes and information on nutritional value. Vegetable Adventures Field Trips- carrot harvesting and information Students who attended a Farm Smart program from March to April had the opportunity to learn what carrots need to grow, the history of colored carrots, their nutritional value, as well as an opportunity to harvest their own traditional and organic carrots. Teachers were also given resources to further enrich their lesson plans to include carrots. Community U-pick- carrot harvest and information Participants learned about colored carrots, the nutritional value of carrots, and were able to harvest carrots from the garden.

Meetings: 3/23/24 Presentation to California Fresh Carrot Advisory Board Symposium on results of selection and breeding for combined nematode and cavity spot resistance and preferred agronomic performance. P Roberts, J. Sidhu, and P. Simon. Bakersfield CA (virtual meeting) 7/8/24 to 7/10/24 P. Roberts, P. Simon, B.-L. Huynh. Genetic mapping of resistance in carrot effective against multiple Meloidogyne hapla populations. 41st International Carrot Conference, Raleigh, NC. (oral presentation) 7/8/24 to 7/10/24 Colley MR, Dawson JC, Zystro J, Hoagland L, Liou M, Myers JR, Silva EM, and Simon PW. 2024. Multienvironment trials inform organic carrot testing and selection strategies. 41st International Carrot Conference, Raleigh, NC. (oral presentation) Blogposts Digging for carrots at the end of the rainbow. Organic Seed Alliance blogpost: https://eorganic.info/node/35347 OSA Blog, 2024 Unearthing the flavors of CANOVI-CIOA carrot trials and farm breeding club. https://seedalliance.org/2024/canovi-cioa-carrot-trials-webinar/ What do you plan to do during the next reporting period to accomplish the goals?Selected field trialing and research activities will continue in Year 4. The winter 2024-25 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 2024. Participatory trials with farmers and seed companies will continue to inform variety release and commercialization, including Ujamaa Seeds, High Mowing, and Johnny\'s in addition to other interested companies. We anticipate release of two orange, nantes populations with flavor and disease resistant backgrounds, as well as release of a purple-yellow-purple population with superior color and flavor in the next year or two based on ratings of uniformity and quality in trial evaluations. Genetic marker development for nematode resistance will continue, and data will be summarized and published. Continue investigations linking microbiomes, nutrient uptake, pathogen resistance, and root nutritional quality and storability among carrot genotypes Greenhouse trials investigating how different growth substrates influence carrot microbiomes and quality will be continued. Manuscripts covering research initiated in CIOA2 investigating relationships between carrot genotype, soil and root microbiomes, and physiological responses quantified using hyperspectral imaging and machine learning and the uptake of toxic heavy metals are in final preparation for publication. Future educational events planned for Year 4: -Hold an industry-stakeholder field day at the UC-DREC Research Station field trial for horticultural production trait and quality evaluation in March, 2025. (P. Simon, J. Sidhu). -Hold an industry-stakeholder field day at the UCR Coachella Research Station field trial for nematode resistance screening in summer 2025. (P. Roberts, P. Simon, T. Waters). -Present research results will be made to California Fresh Carrot Advisory Board Symposium, Spring 2025. (P. Roberts, P. Simon). Deliver an oral presentation to the Apiaceae Workshop at the 2025 Plant and Animal Genome Meetings (P. Simon, P. Roberts). Presentations on breeding for organic ag and the CIOA3 project may be delivered at selected regional vegetable growers meetings including the Great Lakes Fruit, Vegetable, and Farm Market Expo; Midwestern Organic and Sustainable Education Service (MOSES) Conference which are being held virtually. A poster of CIOA will be presented at the Organic Seed Growers\' Conference. Corvallis, OR, February 27th -Mar 1st, 2025. Kayla Quintero (MS student at Purdue) will continue in her MS project, conducting studies investigating the role of carrot microbiomes in mediating resistance against Alternaria and other fungal pathogens. This will include both on-farm trials in Indiana, Vermont, North Carolina and Virginia, and greenhouse trials. At the University of Wisconsin a new MS student Clare Tallamy started at UW-Madison, she will continue microbiome and metabolomic analysis into year 3, whereby we will increase the number of carrot lines included in the analysis, increase the number of locations with field trials, as well as potentially utilizing a Liquid Chromatography-Mass Spectrometry approach to increase the resolution of metabolomic analysis. We anticipate a manuscript to be submitted for consideration at a peer-reviewed journal in late 2023/early 2024. . Also at UW-Madison, the Dawson lab will conduct storage and quality tests on harvested roots from field trials to evaluate the effects of links between microbiomes, nutrient uptake, pathogen resistance, and root nutritional quality and storability among carrot genotypes. The Simon and Dawson labs will conduct carrot texture analyses with a new graduate student Avelina Gaston. Field days with the University of California Cooperative Extension, Kern County, CA A participatory trial of CIOA germplasm will be organized using the Seedlinked platform with growers in the Upper Midwest. Impacts What was accomplished under these goals? Focus Area 1: Cultivar and breeding population development and release 1) Cultivar releases: Four breeding lines were submitted to the USDA for formal release including F7738 (superior flavor and cavity spot resistance), Nbh2306, Nb2159 and Nb3271 (root-knot nematode resistance to Meloidogyne incognita). Farmers and seed companies trialed novel colored breeding lines \"Sunset\" and \'Fantasia\' including trials by organic seed companies and by farmers of the BIPOC-led Ujamaa Seed Cooperative. Ujamaa introduced \'Fantasia\' in commercial seed sales in spring 2024 and is collaborating with OSA on a seed increase for 2025 sales. On-farm and research station sites evaluated red colored breeding lines in WA, CA and Canada. 2) Advanced populations: More than 2043 entries were evaluated in the DREC winter nursery for qualities suitable for organic systems. From that evaluation 31 entries were selected for seed increase or crossing by OSA including orange, red, purple-red, mixed color, and purple selections. Thirty-six breeding populations produced at the OSA Research Farm were sent to the 2024 DREC winter nursery for evaluation and advanced selection with several grown as rootstock for seed company trials. 3) New breeding

populations: Over 200 crosses or seed increases were made by the USDA and OSA to develop and advance new breeding populations combining priority agronomic and market qualities. These included new populations combining superior flavor and texture into lines with nematode and Alternaria leaf blight resistance, uniformity, and yield across multiple production areas. 4) Germplasm screening and regeneration: 19 entries of breeding populations were evaluated at OSA to assess readiness for release and suitability in organic systems and markets. New breeding populations of diverse red and yellow lines were advanced from root selections made at the DREC winter nursery. New seed sources of juicy texture were identified from the 2023-24 winter nursery field trials. Focus Area 2: Expand participatory variety trial and plant breeding network 1) Engagement with Ujamaa Seeds, High Mowing Organic Seeds, and Johnny\'s Selected Seeds in collaborative trials provided informative evaluation and expert feedback in advancing breeding lines for release. 2) In 2024, 3 farms and 3 research stations trialed breeding lines in WA, CA, IN, WI and BC. 3) To engage participants through online networking, OSA hosted a seed grower social and educational platform, the Organic Seed Commons. This space hosts a carrot breeding synergy group for coordinating trialing and education. In 2024 OSA outreach included a fall field day and a webinar presentation on CIOA participatory breeding and trials hosted with eOrganic and the Organic Seed Commons. 4) The Plant Prior Art Repository (PPAR) was envisioned as a tool for defensive publication for plant breeders and seed stewards to establish novel plant varieties and traits as prior art, and a PPAR toolkit on Intellectual Property was created for educational purposes. Informational materials are available to educate users how to protect released germplasm in the public domain. New CIOA germplasm releases are being registered in the public domain. They are being made publicly available and submitted to GRIN. Focus Area 3: Investigate links between microbiomes, nutrient uptake, pathogen resistance, and root nutritional quality and storability among carrot genotypes Two research projects focus on advancing our understanding of root-microbiome interactions. 1) The first, led by Hoagland and Colley and supported by graduate students K. Quintero and K. Zapf, aims to determine the extent to which genetic differences in elemental uptake and resistance to Alternaria are mediated by carrot microbiomes, and whether these beneficial relationships and outcomes can be enhanced through soil and crop management. During the summer of 2024, a set of carrot genotypes that vary in resistance to Alternaria were grown in on-farm field trials in 9 diverse locations across the country. Soil quality, Alternaria ratings, and yield were quantified at each site. Characterization of samples collected from these trials is underway. 2) A smaller on-farm participatory research trial was conducted in Indiana investigated whether a foliar amendment derived from organic substrates alters carrot leaf/root microbiomes, disease severity and quality of carrot taproots. 3) Carrot taproots from field trials in ME, VA, IL, NC, and WI were collected and stored for microbiome assessments associated with Alternaria resistance. 4) In the second study, building upon prior work showing that carrot cultivars exude chemically distinct root exudates that lead to the recruitment of compositionally distinct rhizosphere microbiomes, Freedman, Silva, and Dawson, and supported by grad student C. Tallamy, are evaluating the exudates of 6 carrot cultivars to determine if the chemically distinct root exudates that lead to the recruitment of compositionally distinct rhizosphere microbiomes are consistent across years and growing locations. They are also evaluating variation in root exudate-mediated recruitment of rhizosphere microbiomes across soil types to determine whether likely differences in rhizosphere microbiome composition are also associated with differences in within-root microbiome composition that may affect storability. Root exudates, roots, and soil have been sampled for evaluation of genetic variation and root exudate chemical composition. Focus Area 4: Utilize molecular markers to improve nematode resistance Research in this focus area utilizes molecular markers for nematode resistance to evaluate and select elite carrot populations. New and previously identified nematode resistance sources with M. incognita, M. javanica and M. hapla resistance were advanced in breeding selections and evaluated in two field trials in Coachella, CA and in greenhouse inoculation trials at UC Riverside with roots sent to WI for seed production. These entries were also evaluated in the DREC trial in 2024 to evaluate horticultural quality. Molecular markers are being developed for resistant alleles for all sources of resistance. Focus Area 5: Evaluate and improve carrot flavor, texture and color Assessment of carrot flavor was integrated into all germplasm evaluations and breeding activities since flavor is a priority trait necessary for the successful adoption of new cultivars with quality agronomic traits. Evaluations of texture were also initiated by a new graduate student, A. Gaston. Publications Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: H M Anderson, GA Cagle, EL-W Majumder, E Silva, J Dawson, P Simon, ZB Freedman, Root exudation and rhizosphere microbial assembly are influenced by novel plant trait diversity in carrot genotypes, Soil Biology and Biochemistry, Volume 197, 2024 Type: Websites Status: Published Year Published: 2024 Citation: CIOA web site - general project, carrot information, and gallery of carrots http://eorganic.info/carrotimprovement Progress 09/01/22 to 08/31/23 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:none What opportunities for training and professional development has the project provided?CIOA team advises carrot breeding and variety evaluation for small to medium scale seed companies and carrot farmers engaged in on-farm breeding. We also advise our colleagues at the Univ. of British Columbia enabling a growing network of CA on-farm carrot breeding activities. The project provides access to diverse

genetics along with trainings to skill-up participants delivered through eOrganic and the Organic Seed Commons. These efforts are expanding the number of independent carrot breeders developing varieties for diverse climatic and market needs. As part of education activities, undergraduate students, graduate students, and post-doctorates are also 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, and present in professional conferences. Kathleen Zapf (MS student at Purdue) investigating carrot genotype by microbiome by heavy metal/nutrient uptake - received additional training, completed experiments, presented data and is currently working on manuscripts. Hannah Anderson (MS student at Univ. of Wisconsin-Madison) investigated parallel field and greenhouse studies exploring whether the composition and functional potential of the carrot rhizosphere microbiome is governed by the chemical composition of root exudates. Avelina Gaston (MS student at UW-Madison) is receiving training for developing machine methodologies for testing carrot texture and for investigating the genetics of carrot root texture. Extension activities included creating new project promotion and educational materials for CIOA3, coordinating outreach and evaluation activities, presenting at multiple scientific and food industry conferences, and delivering trainings and educational events. Trials were conducted with organic seed company research farms. 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. Susana Cabrera-Mariz, Iowa State University, engaged in a 4 month research farm internship at Organic Seed Alliance, and is collaborating with CIOA to conduct research on carrot history, domestication, and cultural food pathways as her MS thesis (2024 graduation). 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 to disseminate research updates, timely articles, and related project events (http://eorganic.info/carrotimprovement). 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. Project collaborators hosted public farmer field days in conjunction with trials at the project research sites. Field days coincided with timing of trial evaluations. How have the results been disseminated to communities of interest?Educational events and conference presentations delivered include: Field Days and Trainings: OSA Washington Researcher Field Day, Sep 11, 2023 Webinar: McHenry County College, Carrot participatory plant breeding and on-farm trial evaluations, November 2nd, 2023. 8/17/22 West Madison Field Day, Madison, WI. 8/24/22 Collaborative Plant Breeding Field day at the West Madison Agricultural Research Station, Madison, WI 8/31/23 Field day for industry carrot breeder and production personnel to evaluate breeding materials from the project and from industry sources for root-knot nematode resistance and agronomic performance, Coachella, CA Outreach activities presented on this project by the University of California, Desert Research and Extension Center, Holtville, CA: From 2022 to 2023 Farm Smart delivered carrot outreach programs in nutrition and production to 2908 participants, which includes educators, K-12 students, and community members. Below is a summary of activities delivered: Farm to Summer - Carrots (45 participants) Led an interactive summer program where participants learned about the history of carrots, nutritional information, how they grow, and tasted a variety of carrot preparations, including the various colors. CARES Fall Festival- carrot planting (15 participants) Participants learned about carrots as they planted their own carrot seeds to take home Farm Tours- carrot presentation, research, harvesting (463) While touring the facility, guests learned about colored carrot research taking place at the farm. Farm to Preschool Festival- carrot tasting and facts (1116) Participants tasted carrots and received recipes and information on nutritional value. Vegetable Adventures Field Trips- carrot harvesting and information (992) Students who attended a Farm Smart program from March to April had the opportunity to learn what carrots need to grow, the history of colored carrots, their nutritional value, as well as an opportunity to harvest their own traditional and organic carrots. Teachers were also given resources to further enrich their lesson plans to include carrots. Community U-pick- carrot harvest and information (277) Participants learned about colored carrots, the nutritional value of carrots, and were able to harvest carrots from the garden. Meetings: Hoagland, L., 2023. Soil life and urban soil health assessments. Get the Dirt - Urban & Small Farm Soil Health Conference, Indianapolis, IN (oral presentation) Zapf., K., Simon, P., Lee, L., Hoagland, L., 2023. Carrot genotype and soil properties modulate heavy metal transfer factor on urban farms. Agronomy, Crop Science, Soil Science Societies International Meeting, St. Louis, MO. (poster presentation) Zapf, K. 2022. Interactions between carrot genotypes and soils on heavy metal uptake. Corteva Plant Science Symposium, West Lafayette, IN (poster presentation) Zapf, K., 2022. Are your carrots at risk for heavy metal uptake? Small Farm Conference, Danville IN (poster presentation) Zapf, K.. 2022/ Are your carrots at risk for heavy metal uptake? Indiana Horticulture Conference, West Lafayette, IN (poster presentation) 2/14/23 Presentation to California Fresh Carrot Advisory Board Symposium on results of selection and breeding for combined nematode and cavity spot resistance and preferred agronomic performance. P Roberts, J. Sidhu, and P. Simon. Bakersfield CA (virtual meeting) Anderson, H., E. Silva, J. Dawson, P. Simon, and Z.B. Freedman. Plant-Soil-Microbe Interactions in Organic Vegatable

Cultivar Development. Marbleseed Organic Farming Conference, LaCrosse, WI. (2023). Anderson, H., E. Silva, J. Dawson, P. Simon, and Z.B. Freedman. Assessing the Influence of Root Exudation on Soil Microbial Recruitment across Cultivar Diversity in Organic Vegetable Production. Soil Science Society of America Annual Meeting. St. Louis, MO. (2023). Blogposts Digging for carrots at the end of the rainbow. Organic Seed Alliance blogpost: https://eorganic.info/node/35347 OSA Blog, Midwest Collaborative Plant Breeding Field Day https://seedalliance.org/2022/midwest-collaborative-plant-breeding-field-day-highlights/ 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 will continue in Year 3 - namely the winter 2023-24 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 2024. Marker work for nematode resistance will continue, and data will be summarized published. Future educational events planned for Year 2: Presentations on breeding for organic ag and the CIOA3 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. MS student Kathleen Zapf will finalize the results of her experiments investigating the role of carrot root microbiomes in mediating heavy metal uptake, submit publications and graduate in May 2024. Kayla Quintero (MS student at Purdue) will start in January 2024, and will conduct studies investigating the role of carrot microbiomes in mediating resistance against Alternaria and other fungal pathogens. This will include both on-farm trials in Indiana, Vermont and Virginia, and greenhouse trials. At the University of Wisconsin a new MS student Clare Tallamy started at UW-Madison, she will continue microbiome and metabolomic analysis into year 3, whereby we will increase the number of carrot lines included in the analysis, increase the number of locations with field trials, as well as potentially utilizing a Liquid Chromatography-Mass Spectrometry approach to increase the resolution of metabolomic analysis. We anticipate a manuscript to be submitted for consideration at a peer-reviewed journal in late 2023/early 2024. . Also at UW-Madison, the Dawson lab will conduct storage and quality tests on harvested roots from field trials to evaluate the effects of links between microbiomes, nutrient uptake, pathogen resistance, and root nutritional quality and storability among carrot genotypes. The Simon and Dawson labs will conduct carrot texture analyses with a new graduate student Avelina Gaston. At Organic Seed Alliance we will continue national de-centralized, participatory on-farm trials. We will also educate trial participants in opportunities for on-farm carrot breeding and provide access to CIOA breeding populations for their breeding activities. A participatory trial of CIOA germplasm will be organized using the Seedlinked platform with growers in the Upper Midwest. Impacts What was accomplished under these goals? Focus Area 1: Cultivar and breeding population development and release 1) Cultivar releases:. R6636 is commercially available under the cultivar name \'Carnelian\', and 2023 represented the second year of sales from High Mowing Organic Seeds. Farmers and seed companies trialed the diversity population named \'Fantasia\' including a dozen farmers of the BIPOC-led Ujamaa Seed Cooperative. Ujamaa expressed interest in introducing \'Fantasia\' in commercial seed sales in 2024. 2) Advanced populations: More than 1500 entries were evaluated in the DREC winter nursery for qualities suitable for organic systems. From that evaluation 212 entries were selected for seed increase by OSA including orange, red, purple-red, and purple selections. Thirty-six breeding populations produced at the OSA Research Farm were sent to the 2023 DREC winter nursery for evaluation and advanced selection with several grown as rootstock for seed company trials. 3) New breeding populations: Over 90 crosses were made to develop new breeding populations combining priority agronomic and market qualities New populations utilize marker assisted selection to be with the PPB network and breeding efforts of project partners. 4) Germplasm screening and regeneration: 121 entries of diverse carrot stocks were evaluated at OSA for suitability in organic systems and markets. Of these 121, 50 entries from the PI-breeding collection were grown as a representation of the history and diversity of history of carrot for educational purposes. Breeding populations were advanced of 17 populations at OSA including varied purple, yellow orange crosses, new strain crosses of red, advanced orange populations, rainbow mix (\'Fantasia\'). Cavity spot resistance screening identified CIOA entries F5367, U8284, and Nb8525 to present a fairly high level of resistance in field trials. Additional testing is needed to confirm these early observations. New seed sources of juicy texture were identified from the 2023-24 winter nursery field trials. Focus Area 2: Expand participatory variety trial and plant breeding network 1) Seed company engagement provided multiple project benefits to enhance participatory breeding in 2023 including evaluation and expert feedback to the breeding team on the qualities and commercial potential of CIOA populations and develops direct relationships for commercial availability and distribution of varieties once released. In 2023 High Mowing (Vermont), Peace Seeds (Colorado), Levine Seeds (Hawaii), and Ujamaa Seeds (National cooperative of BIPOC seed growers) all trialed advanced populations of CIOA lines to assess commercialization potential. Ujamaa has requested permission to sell \'Fantasia\' in 2024 and other companies are providing feedback with intention of either commercializing CIOA lines or engaging in additional breeding efforts. 2) Fifty farmers across the US conducted on-farm trials of orange and novel color varieties and breeding populations coordinated through Seedlinked. To expand impacts trial coordinators collaboratd with the, CANOVI, the Canadian organic seed

initiative who coordinated with 50 Canadian farmers in the same trial. Farmers reported on evalutions and engaged socially through Seedlinked (https://seedlinked.com/run-variety-trials-on-seedlinked/). January 2024 we will co-host a webinar on trial results through eOrganic and the Organic Seed Commons carrot breeding network (https://www.organicseedcommons.org/spaces/7291805/members/top). 3) To engage participants through online networking, OSA hosts a new network through the Organic Seed Commons. The project created a carrot breeding synergy group within the OSC for coordinating trialing and education. In 2023 OSA\'s outreach included a fall field day and a webinar presentation on CIOA participatory breeding and trials for the McHenry County College in Illinois. 4) The Plant Prior Art Repository (PPAR) serves as the defensive publication for plant breeders and seed stewards to establish novel plant varieties and traits as prior art. Informational materials are being developed to educate users how to protect released germplasm in the public domain. New CIOA germplasm releases for PPB are being registered. Focus Area 3: Investigate links between microbiomes, nutrient uptake, pathogen resistance, and root nutritional quality and storability among carrot genotypes Two research projects focus on advancing our understanding of root-microbiome interactions. The first led by Hoagland and Colley verifies whether the composition and functional potential of microbiomes in carrot taproots are stable across a broad set of environments and determines if this influences crop field performance and quality. Greenhouse trials evaluate relationships between root microbiomes, disease resistance, and the quality and storability of carrot taproots. In that study: 1) Research investigating relationships between carrot genotype, feedback effects on soil microbial community structure, and resilience against parasitic nematodes has been completed. A manuscript covering this project is underway. 2) Research started in CIOA2 investigating relationships between carrot genotype, root microbiomes, and heavy metal uptake was continued with field and greenhouse trials. A manuscript covering the field trials is underway, and results of the greenhouse trials are being analyzed. 3) Trails were conducted in Purdue\'s automated controlled environment phenotyping facility (AAPF) to determine whether hyperspectral imaging could be used to quantify genetic differences in cadmium and uptake. A manuscript covering the results is underway. 4) Carrot taproots from field trials in Washington and Wisconsin were processed and stored for microbiome assessments associated with Alternaria resistance and genotypes were identified for a set of on-farm trials that will occur in 2024. The on-farm trials will be paired with greenhouse trials. 5) In the second study led by Freedman, Silva, and Dawson, a graduate student (Hannah Anderson; UW-Madison Soil Science MS program) analyzed the metabolome of rhizosphere and bulk soil from two time points across the growing season demonstrated that the four cultivars tested recruited distinct microbiomes to their rhizosphere, and this trend was not observed in the bulk soil where there was no cultivar effect. This suggests that the plant\'s governance of the soil microbiome does not extend very far from the root. The metabolomics analysis uncovered that the chemical signature of the plant root exudates was also distinct across cultivars and was most distinct for the heirloom variety and the nematode resistant variety. Interestingly, there were also detectable differences in the bulk soil metabolome across cultivars, suggesting that the plant chemical influence extends further into the soil than the plant\'s influence on the microbiome. . Focus Area 4: Utilize molecular markers to improve nematode resistance Research in this focus area utilizes molecular markers for nematode resistance to evaluate and select elite carrot populations. New and previously identified nematode resistance sources with M. incognita, M. javanica and(or) M. hapla resistance were advanced in breeding selections and evaluated in field trial in Coachella, CA (March-August 2023) and WSU Othello Station, WA (June-October 2023) and in greenhouse inoculation trials at UC Riverside and roots sent to WI. These entries were also evaluated in the DREC trial to evaluate horticultural quality. Molecular markers are being developed. Focus Area 5: Evaluate and improve carrot flavor, texture and color Assessment of carrot flavor was integrated into all germplasm evaluations and breeding activities since flavor is a priority trait necessary for the successful adoption of new cultivars with quality agronomic traits. Evaluations of texture were also initiated by a new UW-Madison MS student, Avelina Gaston. Publications Type: Theses/Dissertations Status: Published Year Published: 2023 Citation: Anderson, H. (2023) Root exudation and rhizosphere microbial recruitment are influenced by novel cultivar development in organic carrot production. University of Wisconsin-Madison. Type: Journal Articles Status: Published Year Published: 2023 Citation: Trivi?o, N., Rodriguez-Sanchez, A., Filley, T., Camberato, J., Colley, M., Simon, P., Hoagland, L., 2023. Carrot genotypes differentially alter soil bacterial communities and decomposition of plant residue in soil. Plant and Soil doi.org/10.1007/s11104-023-05892-0. **Progress** 09/01/21 to 08/31/22 **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?CIOA team advises carrot breeding and variety evaluation for small to medium scale seed companies and carrot farmers engaged in on-farm breeding. We also advise our colleagues at the Univ. of British Columbia enabling a growing network of CA on-farm carrot breeding activities. The project provides access to diverse genetics along with trainings to skill-up participants delivered through eOrganic and the Organic Seed Commons. These efforts are expanding the number of independent carrot breeders developing varieties for diverse climatic and market needs. As part of education activities, undergraduate students, graduate students, and post-doctorates are also 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, and present in professional conferences. In year 1 co-PI Colley, completed her PhD including CIOA research on genotype by environment by management system interactions. Umut Bicim (BS student at Purdue University) received training and worked with post-doc Alejandro Rodriguez-Sanchez to quantify soil and root microbiomes in a carrot genotype X microbiome X pathogen resistance (nematode) experiment. Kathleen Zapf (MS student at Purdue) investigating carrot genotype X microbiome X heavy metal/nutrient uptake - received training and is conducting experiments. Hannah Anderson (MS student at Univ. of Wisconsin-Madison) investigating parallel field and greenhouse studies exploring whether the composition and functional potential of the carrot rhizosphere microbiome is governed by the chemical composition of root exudates. Extension activities included creating new project promotion and educational materials for CIOA3, coordinating outreach and evaluation activities, presenting at multiple scientific and food industry conferences, and delivering trainings and educational events. Trials were conducted with organic seed company research farms. 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. 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 to disseminate research updates, timely articles, and related project events (<http://eorganic.info/carrotimprovement>). 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. Project collaborators hosted public farmer field days in conjunction with trials at the project research sites. Field days coincided with timing of trial evaluations. How have the results been disseminated to communities of interest?Educational events and conference presentations delivered include: Outreach: August 21st 2022 Farm to Flavor Event, Madison Wisconsin Field Days and Trainings: OSA Washington Researcher Field Day, Sep 26, 2022 OSA Washington Community Field Day, Sep 26, 2022 Webinar: hosted on eOrganic and the Organic Seed Commons, Breeding carrots for production, resilience, flavor and fun in organic systems. <https://eorganic.info/node/35336> Webinar: Breeding Carrots for Production, Resilience, Flavor and Fun in Organic Systems, March 31, 2022 -Viewed 1200 times since publishing / URL: <https://www.youtube.com/watch?v=xdsg2NSPZ0w> CIOA supported and presented at the International Carrot Conference, Aug 29-30, 2022 (\~75 participants). Get the Dirt: Urban Agriculture Soil Health Conference (120 participants) West Lafayette, IN 2022. - Hoagland, L. - CIOA research investigating carrot genotype - heavy metal - microbiome research covered eOrganic webinar: Combining soil amendments and varietal development to prevent pathogens and heavy metal uptake (2022). Hoagland, L. - CIOA research investigating carrot genotype - heavy metal - microbiome research covered Improving nutrient use efficiency and crop productivity with soil health. Bi County Soils Workshop. Delphi, IN (2022) - Hoagland, L. - CIOA research investigating carrot genotype X microbiome X NUE research covered 8/17/22 West Madison Field Day, Madison, WI. 8/24/22 Collaborative Plant Breeding Field day at the West Madison Agricultural Research Station, Madison, WI Meetings: International Carrot Conference: Colley and McKenzie, \"Creating connections, igniting inspiration and imagination, and having fun through Participatory Plan Breeding\". <http://www.internationalcarrots.org/uploads/1/2/7/7/127726097/2022_icc_conference_-_program_book_final.pdf> Hoagland, L. How are Purdue researchers using the national plant germplasm collections? North Central Regional Plant Germplasm Repository Meeting, On-line (2022). Hoagland, L. Organic vs. conventional cropping systems: impacts on root microbiomes and their functions. III International Organic Fruit Symposium and I International Organic Vegetable Symposium. On-line (2021) Blogposts Digging for carrots at the end of the rainbow. Organic Seed Alliance blogpost: <https://eorganic.info/node/35347> and <https://seedalliance.org/2022/digging-for-carrots-at-the-end-of-the-rainbow/> OSA Blog, Midwest Collaborative Plant Breeding Field Day <https://seedalliance.org/2022/midwest-collaborative-plant-breeding-field-day-highlights/> 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 will continue in Year 2 - namely the winter 2022-23 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 2023. Marker work for nematode resistance will continue, and data will be summarized published. Future educational events planned for Year 2: Presentations on breeding for organic ag and the CIOA3 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. New post-doc Dr. Marian Luis will start at Purdue University and conduct research investigating carrot genotype X microbiome X pathogen

resistance/taproot quality experiments. MS student Kathleen Zapf will continue her studies investigating carrot genotype X microbiome X heavy metal/nutrient uptake experiments. Publications submitted. Microbiome and metabolomic analysis will continue into year 2, whereby we will increase the number of carrot lines included in the analysis as well as potentially utilizing a Liquid Chromatography-Mass Spectrometry approach to increase the resolution of analysis. We will also enhance the portion of the analysis dedicated to better understanding how each carrot line will impact important microbial functions. The MS student on the project will defend her MS thesis in Winter, 2023 and possibly stay to complete her PhD on this project. We anticipate a manuscript to be submitted for consideration at a peer-reviewed journal in late 2023/early 2024 as well as data to be disseminated as presentations at the West Madison Field Day and a meeting of international scope like the Soil Science Society of America Annual Meeting. At the University of Wisconsin the Dawson lab will conduct storage and quality tests on harvested roots from field trials to evaluate the effects of links between microbiomes, nutrient uptake, pathogen resistance, and root nutritional quality and storability among carrot genotypes. The Simon lab will conduct carrot texture analyses with a new graduate student. **Impacts** What was accomplished under these goals? Focus Area 1: Cultivar and breeding population development and release 1) Cultivar releases: Three new varieties bred during CIOA 1-2 are now ready for commercial release with formal releases from the USDA and Organic Seed Alliance (R6220, Y1246, and R6636). In 2022, 5 organic seed companies evaluated the 3 varieties to determine interest in commercialization. R6636 was produced on 2 participatory organic farms and is now available commercially from High Mowing Organic Seeds under the name Carnelian. Other releases are advancing to commercialization. 2) Advanced populations: More than 1500 entries were evaluated in the DREC winter nursery for qualities suitable for organic systems. From that evaluation 95 entries were selected for seed increase by OSA including orange, red, purple-red, and purple selections. 70 breeding populations produced at the OSA Research Farm were sent to the 2023 DREC winter nursery for evaluation and advanced selection with several grown as rootstock for seed company trials. 3) New breeding populations: Over 75 crosses were made to develop new breeding populations combining priority agronomic and market qualities - flavor, novel visual appearance, and agronomic traits including Alternaria leaf blight resistance, root-knot nematode resistance, cavity spot resistance, early stand establishment and seedling vigor, and high nutritional value. New populations utilize marker assisted selection to be with the PPB network and breeding efforts of project partners. 4) Germplasm screening and regeneration: 72 entries of diverse carrot stocks were evaluated at OSA for suitability in organic systems and markets and 18 advanced populations were increased at OSA. Focus Area 2: Expand participatory variety trial and plant breeding network 1) To expand the number of farms and seed companies participating in the project through participatory on-farm trials and on-farm plant breeding (PPB), on-farm trials included small seed companies in VT, CO, and ME with plans to expand in 2023. 2) Using the online platform SeedLinked to collect and share trial evaluations participant evaluations informed release decisions of new varieties. Trial coordination will be implemented in 2023 to evaluate advanced populations. 3) To engage participants through online networking, OSA hosts a new network through the Organic Seed Commons. The project created a carrot breeding synergy group within the OSC for coordinating trialing and education, currently for 16 members. A carrot breeding webinar co-hosted with eOrganic trained participants in fundamentals of carrot genetics and selection. The research team submitted 7 CIOA varieties in conference field trials, presented a CIOA poster, and delivered an oral presentation. Yr 1 outreach featured the CIOA trials in the annual OSA activities reported in the Field Day list. Storage and quality tests on harvested roots from field trials are evaluated in Focus Area 3. 4) The Plant Prior Art Repository (PPAR) serves as the defensive publication for plant breeders and seed stewards to establish novel plant varieties and traits as prior art. Publishing plant varieties and traits in the repository puts these inventions into the public domain and protects them from patenting. CIOA partners are working with the US Patent Office to promote its use to ensure varieties and traits published as prior art are not awarded patents to other individuals or companies. Informational materials are being developed to educate users how to protect released germplasm in the public domain. New CIOA germplasm releases for PPB will be registered. Focus Area 3: Investigate links between microbiomes, nutrient uptake, pathogen resistance, and root nutritional quality and storability among carrot genotypes Two research projects focus on advancing our understanding of root-microbiome interactions. The first led by Hoagland and Colley verifies whether the composition and functional potential of microbiomes in carrot taproots are stable across a broad set of environments (CA, WI, IN, VT, VI), and determines if this influences crop field performance and quality. Corresponding greenhouse trials evaluate relationships between root microbiomes, disease resistance, and the quality and storability of carrot taproots. In that study: 1) Research started in CIOA2 investigating relationships between carrot genotype, feedback effects on soil microbial community structure, and resilience against parasitic nematodes was continued. Root endophyte and soil microbiome analyses from greenhouse studies were sequenced and bioinformatic analyses are underway. 2) Research started in CIOA2 investigating relationships between carrot genotype, root microbiomes, and heavy metal uptake was continued with a second round of field trials on 10 urban farms across Indiana. 3) A preliminary trial was conducted in Purdue's automated controlled environment phenotyping facility (AAPF) to assess carrot growth and timing for quantifying plant performance using hyperspectral imaging and CT root scanning. A follow-up experiment to identify the best

wavelengths and algorithms for quantifying differences in carrot genotype responses to heavy metals and estimate uptake is underway. A further experiment integrating microbiome dynamics is expected in the spring. 4) Carrot taproots from field trials in Washington and Wisconsin were processed and stored for microbiome and other assays that will begin, and publications covering results are expected in the next year. In the second study led by Freedman, Silva, and Dawson, a graduate student (Hannah Anderson; UW-Madison Soil Science MS program) started January 2022. Parallel field and greenhouse studies explored the relationship between composition, functional potential of the carrot rhizosphere microbiome, and chemical composition of root exudates. The first-year effort included a field trial and a greenhouse trial with four carrot cultivars. The field experiment was a success, and the greenhouse experiment was not, due to relatively weak carrot growth. From the field experiment, samples were taken for microbiome analysis from two soil compartments, including the rhizosphere (i.e. soil directly in contact with the carrot taproot) as well as bulk soil (that is, soil in the plot, but not in contact with the taproot) at three time points across the growing season. DNA has been extracted from all samples and is being sequenced for microbial community analysis in the coming months. For metabolomics, a protocol was developed and used to extract root exudates from carrot roots. Samples were sent for metabolomic analysis of rhizosphere and bulk soil from two time points across the growing season. Relationships between carrot root exudate chemistry, soil microbiome characteristics, and carrot quality are being evaluated. Focus Area 4: Utilize molecular markers to improve nematode resistance Research in this focus area utilizes molecular markers for nematode resistance to evaluate and select elite carrot populations. Molecular markers are being developed to confirm the identity of resistance genes segregating in breeding stocks derived from these sources and utilize those markers to select parental roots with resistance alleles from multiple genes to assure strong resistance during the breeding process. One new nematode resistance source was identified with M. incognita resistance was advanced and evaluated in trials in Coachella, CA, and roots sent to WI. These entries were also evaluated in the DREC trial to evaluate horticultural quality. Focus Area 5: Evaluate and improve carrot flavor, texture and color Assessment of carrot flavor was integrated into all germplasm evaluations and breeding activities since flavor is a priority trait necessary for the successful adoption of new cultivars with quality agronomic traits. Organoleptic and machine evaluations of texture were also initiated. **Publications** - Type: Theses/Dissertations Status: Published Year Published: 2022 Citation: Colley, M. (2022) Critical Experiences in Participatory Approaches to build up Organic Plant Breeding and Organic Seed Systems. Wageningen University and Research. <https://edepot.wur.nl/578477>. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Colley, M and McKenzie, L. (2022) Creating connections, igniting inspiration and imagination, and having fun through participatory plant breeding with carrots. 40th International Carrot Conference.

↑ Return to Index

Combination of Major Genes for Improvement of Organic Specialty Corn Varieties (comgi)

Accession No.	1026699
Project No.	IOW05656
Agency	NIFA IOW\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34896
Proposal No.	2021-02928
Start Date	01 SEP 2021
Term Date	31 AUG 2025
Grant Amount	$1,438,460
Grant Year	2021
Investigator(s)	Lubberstedt, T.; Tracy, WI, F.; Delate, KA, .; Scott, MA, PA.
Performing Institution	IOWA STATE UNIVERSITY, 2229 Lincoln Way, AMES, IOWA 50011

NON-TECHNICAL SUMMARY

This project addresses the need for corn varieties suited to organic production systems and organic seed production, with a focus on sweet corn and specialty corn. The long-term objective is to establish efficient procedures to exploit major genes and major effect quantitative trait loci available in maize, that are aligned with the organic philosophy and to our knowledge have not been systematically applied in any breeding program to date.This work has the potential to change the organic seed production industry to make it better aligned with the organic ideals of sustainable nutritious food production. If successful, more companies will market corn seed that is produced organically and has been developed with the needs of organic producers in mind. The cornerstone of the outreach plan is the practical assessment of the hybrids developed in this project and their uptake by organic producers. Organic farmers will be full partners in the project and assist scientists in evaluating sweet and specialty corn lines for productivity under organic conditions. Field Days will highlight specific commercial organic varieties alongside field corn hybrids adapted for regional organic conditions. This multi-state interdisciplinary project will offer a variety of programs for sharing research results and providing information, demonstrations, and training on the principles and practices of organic plant breeding and use of tools/technology derived from this research. Data will be collected from each point of contact with farmers across all sites to allow for detailed analysis of the tools necessary to encourage widespread adoption of the practices and techniques developed within this project. In addition to research responsibilities, team members have been involved extensively in diverse education and extension programs, working with a wide range of client groups. Technology transfer techniques in this project include 1) Field Days (5 per year in Yrs 2-4); 2) conference workshops (1 per year); 3) classroom presentations (at least one per year), 4) publications, including journal articles (3) an Extension publication on \"Field and Sweet Corn Varieties for Organic Crop Production in the Midwest,\" and 5) electronic and social media: websites, webinars (one/year through e-Organic or another national carrier), podcasts (one/year posted on project websites) and an interactive blog where participants can upload questions and comments on research results. An advisory team, representing producers, seed companies, Extension, and researchers will help provide comprehensive management plans in addition to evaluating project progress and success. PIs will meet regularly with field corn and sweet corn breeders and growers in each state and will keep them informed of progress. Co-PI Tracy works closely with a number of the sweet corn seed retailers that focus on the organic market, and we will send the best hybrids to these companies for evaluation under certified organic conditions ranging from Maine to California.

OBJECTIVES

Organic corn production, and the transition from conventional to organic corn production, is affected by (1) declining prices for organic products, and (2) by climate change - facilitating spread of novel pests and diseases, and respective races and isolates. For this reason, we will focus on high margin organic sweet and specialty corn breeding in this proposal, and incorporation of genetic tools to enable efficient breeding of respective varieties. The goal of this work is to develop efficient tools and strategies for the utilization of major genes affecting pest and disease resistance, quality, reproductive and other agronomic traits in organic sweet and specialty corn breeding. Specifically, this includes (i) development and application of functional markers for efficient transfer of genes between sweet, field, and specialty corn, (ii) use of breeding strategies including DH technology for efficient transfer of major genes or QTL into elite germplasm, and (iii) on farm trials for evaluation of experimental cultivars under organic farm conditions.

APPROACH

The yield improvement of corn in the U.S. since the introduction of hybrid varieties in the 1940s is a remarkable success story. The four-fold increase in productivity achieved in this time period allowed the development of our modern food industry, kept food prices low, and provided the base for sustained economic expansion. This success is due in large part to the application of technology by large seed companies, essentially mechanizing and automating the process of plant breeding with selection for yield. Over the same time-span corn evolved from a genetic to a genomic model plant, with meanwhile multiple completely sequenced genomes available including a recently sequenced sweet corn genome, numerous characterized genes and novel technologies such as genome editing available to conventional corn breeding. While some technologies do not comply with organic crop production, others are compliant (such as DNA markers) and have the potential to substantially advance organic crop breeding, if properly incorporated. Organic agriculture encourages the sustainable production of nutritious food. Corn is an important component of organic production systems, but the majority of seed available to producers are modern varieties that are products of the industrial plant breeding system and are not well suited to the needs of organic producers. Rigorous use of organic compliant technologies will help to reduce the yield gap of varieties developed for the conventional versus the organic market. Moreover, they will allow us to efficiently utilize major natural genetic variation available in maize for development of more nutritious or resilient varieties, or to develop novel specialty corn types. Tremendous opportunity exists to develop new corn varieties with characteristics valued by organic producers. Such characteristics include:- High quality sweet corn with resistance to a number of pests- Novel traits allowing organic identity preservation- Novel specialty types such as waxy and white corn- Native insect resistance - conventional corn relies on transgenes for insect resistance, so conventional breeders don\'t select for this trait- Disease resistance - major genes to control virus and fungal diseases are available within maize and can be utilized more efficiently based on marker-assisted selection strategies. Corn breeding has rapidly embraced new technologies (e.g., DHs and genomic selection) in order to increase the rate of gain. Companies able to achieve a high rate of gain are rewarded by capturing market share with superior products. Plant breeding programs that do not market organic varieties focus their efforts on two traits that commodity grain prices are based on, i.e., grain yield and ability to dry well in the field. This narrow focus allows breeders to make very high rates of gain. The rate of gain from breeding decreases as the square of the number of traits under selection. Because breeders of organic varieties must focus on many traits, their rate of gain is necessarily lower. Unless organic breeders develop new technologies to increase their rate of gain, organic corn varieties will continue to fall behind non-organic varieties, creating a barrier for adoption of organic practices. Conversely, consequent implementation of organic compliant breeding technologies that facilitate the improvement of many traits simultaneously will allow organic breeders to increase their rate of gain in the direction desired by organic producers, but also to rapidly incorporate natural traits in response to novel market opportunities, in response to the consequences of a changing climate such as novel pathogens, respective races, and abiotic stress tolerance. The most important trait, grain yield, is quantitatively inherited. Modern breeding programs employ genomic selection in conjunction with other methods to accelerate the breeding cycle, such as use of winter nurseries and doubled haploid (DH) technologies, to maximize genetic gains. Recently granted USDA projects support incorporation of genomic selection and DH technologies in both organic and sweet corn breeding (2020-51300-02117; SweetCAP). However, significant progress has also been made in the identification and isolation of major genes in maize, driven by advances in maize genomics. While the first reference genome sequence from maize inbred line B73 was obtained in 2009, high quality genome sequences are meanwhile available of more than 40 additional inbred lines. Consequent application of genetic and genomic resources and approaches led to isolation of multiple genes of agronomic interest. These include genes controlling bacterial, virus, and fungal disease resistance, plant architecture, kernel quality, kernel coloration, reproductive

mechanisms, among others. Conventional breeding programs have different options, how to incorporate major genes in their varieties, including transgenic methods and genome editing, which are not compliant with organic regulations. In contrast, both conventional and organic maize breeding can exploit DNA marker technology to efficiently transfer important major maize genes, as well as major QTL, into elite germplasm. Development of robust markers assays can be challenging due to genomic properties of respective genes (such as duplicated sequences), genetic background effects, linkage of different genes of interest in repulsion phase, among others. Once available, such gene-derived functional markers can be employed for backcrossing, forward breeding, gene stacking, and F2 enrichment among others, which are most efficiently used in combination with DH technology. The purpose of this project is to build a platform to make agronomically important major genes and major QTL available for marker-based introgression into organic breeding materials in conjunction with DH technology not using toxic chemicals in the process, while developing advanced sweet and specialty corn inbred lines for proof of concept. Goals / Objectives Organic corn production, and the transition from conventional to organic corn production, is affected by (1) declining prices for organic products, and (2) by climate change - facilitating spread of novel pests and diseases, and respective races and isolates. For this reason, we will focus on high margin organic sweet and specialty corn breeding in this proposal, and incorporation of genetic tools to enable efficient breeding of respective varieties. The goal of this work is to develop efficient tools and strategies for the utilization of major genes affecting pest and disease resistance, quality, reproductive and other agronomic traits in organic sweet and specialty corn breeding. Specifically, this includes (i) development and application of functional markers for efficient transfer of genes between sweet, field, and specialty corn, (ii) use of breeding strategies including DH technology for efficient transfer of major genes or QTL into elite germplasm, and (iii) on farm trials for evaluation of experimental cultivars under organic farm conditions. Project Methods The yield improvement of corn in the U.S. since the introduction of hybrid varieties in the 1940s is a remarkable success story. The four-fold increase in productivity achieved in this time period allowed the development of our modern food industry, kept food prices low, and provided the base for sustained economic expansion. 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Such characteristics include:- High quality sweet corn with resistance to a number of pests- Novel traits allowing organic identity preservation- Novel specialty types such as waxy and white corn- Native insect resistance - conventional corn relies on transgenes for insect resistance, so conventional breeders don\'t select for this trait- Disease resistance - major genes to control virus and fungal diseases are available within maize and can be utilized more efficiently based on marker-assisted selection strategiesCorn breeding has rapidly embraced new technologies (e.g., DHs and genomic selection) in order to increase the rate of gain. Companies able to achieve a high rate of gain are rewarded by capturing market share with superior products. Plant breeding programs that do not market organic varieties focus their efforts on two traits that commodity grain prices are based on, i.e., grain yield and ability to dry well in the field. This narrow focus allows breeders to make very high rates of gain. The rate of gain from breeding decreases as the square of the number of traits under selection. Because breeders of organic varieties must focus on many traits, their rate of gain is necessarily lower. Unless organic breeders develop new technologies to increase their rate of gain, organic corn varieties will continue to fall behind non-organic varieties, creating a barrier for adoption of organic practices. Conversely, consequent implementation of organic compliant breeding technologies that facilitate the improvement of many traits simultaneously will allow organic breeders to increase their rate of gain in the direction desired by organic producers, but also to rapidly incorporate natural traits in response to novel market opportunities, in response to the consequences of a changing climate such as novel pathogens, respective races, and abiotic stress tolerance.The most important trait, grain yield, is quantitatively inherited. Modern breeding programs employ genomic selection in conjunction with other methods to accelerate the breeding cycle, such as use of winter nurseries and doubled haploid (DH) technologies, to maximize genetic gains. Recently granted USDA projects support incorporation of genomic selection and DH technologies in both organic and sweet corn breeding (2020-51300-02117; SweetCAP). 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maize inbred line B73 was obtained in 2009, high quality genome sequences are meanwhile available of more than 40 additional inbred lines. Consequent application of genetic and genomic resources and approaches led to isolation of multiple genes of agronomic interest. These include genes controlling bacterial, virus, and fungal disease resistance, plant architecture, kernel quality, kernel coloration, reproductive mechanisms, among others. Conventional breeding programs have different options, how to incorporate major genes in their varieties, including transgenic methods and genome editing, which are not compliant with organic regulations. In contrast, both conventional and organic maize breeding can exploit DNA marker technology to efficiently transfer important major maize genes, as well as major QTL, into elite germplasm.Development of robust markers assays can be challenging due to genomic properties of respective genes (such as duplicated sequences), genetic background effects, linkage of different genes of interest in repulsion phase, among others. Once available, such gene-derived functional markers can be employed for backcrossing, forward breeding, gene stacking, and F2 enrichment among others, which are most efficiently used in combination with DH technology. The purpose of this project is to build a platform to make agronomically important major genes and major QTL available for marker-based introgression into organic breeding materials in conjunction with DH technology not using toxic chemicals in the process, while developing advanced sweet and specialty corn inbred lines for proof of concept. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Organic farmers, Organic organizations, Plant breeders, Seed producers, Seed processors Changes/Problems:In Madison we had extreme weather result in 2024. We did lose some experimental materials but we were able to accomplish most of our goals. What opportunities for training and professional development has the project provided?Two Ph.D. students are currently involved, Mercy Fakude (Lübberstedt) and Tae-Chun Park (Scott). Wisconsin Ph.D. student Carl Branch managed the SHGD nursery in Madison, where he made numerous backcrosses to the appropriate parents. Those backcrosses are now growing in Chile in preparation of further backcrossing and selfing. Tae-Chun Park is a 3rd year Ph.D. candidate in the Interdepartmental Plant Biology Program at Iowa State University. He was trained in developing molecular markers for major genes used in this project. In addition, the Scott group trained student interns (e.g., Hannah Clubb) in field operations and seed inventory management. Lübberstedt hosted an intern (Irvin Sosa) from University Puerto Rico Mayaguez, a Hispanic Serving Institution. Robert Turnbull and Josiah Pollock (Extension Program Specialists) were trained in on-farm experimental protocols and data analysis for this project (Delate). Wisconsin: At different times three Ph.D. Candidates we\'re funded partially on this work. All three defended their dissertations during the reporting period, Lexi Wilson, Kathleen McCluskey, and Carl Branch. All three have successfully gotten positions in the plant breeding related fields. How have the results been disseminated to communities of interest?Co-PI Delate is organizing the annual Iowa Organic Conference, where project participants Lubberstedt and Fakude participated in 2023, and will together with co-PI Scott participate in 2024. For 2024, a lunch session with stakeholders is planned. Lübberstedt, Scott, Tracy, and Delate as well as students have been actively participating with oral or poster presentations in various meetings and conferences in 2023 and 2024 (ASTA, CSSA, RF Baker Symposium, Maize Genetics Conference, NAPB, Iowa Organic Conference, among others). Mercy Fakude will present a poster at the 2024 CSSA meeting. Co-PI Tracy Had the opportunity to present parts of this work at the AG food and human values conference in Syracuse NY. Tracy also was able to present some of this work as an invited speaker in the organic plant breeding course a Coimbra Portugal. What do you plan to do during the next reporting period to accomplish the goals?Objective 1: Completing publication on Functional Markers. Using functional markers in development of improved sweet corn and breads and ultimately hybrids. Objective 2: Evaluation of Ga2 inducer candidates Sweet corn DH line development, carrying SHGD Continue incorporation of desirable alleles into sweet corn DH material. Investigate the extent within sweet corn germplasm of the ability to overcome pollen exclusion conferred by Ga1 and Ga2 Specialty corn: Screen for individuals with desired gene combinations. At Wisconsin we will be continuing to evaluate the doubled haploids generated through this program both in terms of performance and also in terms of spontaneous doubling. Objective 3: Delate: Trials conducted in 2024 will be repeated in 2025. Impacts What was accomplished under these goals? Impact statement: This proposal outlines a plant breeding approach that facilitates combination of independent genetic loci in breeding programs. This approach will impact breeding programs focused on production of organic specialty corn varieties, which often require multiple genetic loci to create a desired product. The ability to produce improved varieties faster benefits the public by making products made from the improved varieties less expensive to make, higher quality, and safer while reducing negative impacts on the environment. Objective 1: Functional marker development Functional marker development has been completed. Each group has marker assays available as needed - or receive help from other groups with genotyping as needed. Tae-Chun Park is working on a review paper on functional markers, to be submitted to Frontiers in Plant Science. At Wisconsin functional markers are being incorporated in breeding efforts. Objective 2: Use of breeding strategies including DH technology for efficient transfer of major genes or QTL into elite germplasm Ga2 haploid inducer development: In summer 2024, evaluation of individual progenies derived from different Ga2-haploid -inducer families was continued. Bulk pollen per family (18) was used to pollinate the conventional hybrid Viking 51-95UP to determine induction ability (data not available yet) and pollen of 5-6 individuals per family were used to pollinate the Ga2 and Ga1 donor, to evaluate their ability to overcome the

respective crossing barrier. As expected most of the individuals were able to generate medium to decent seed set on the Ga2 donor. In addition, all of the Ga2 families derived from a haploid inducer based on the public line Mo17 were able to overcome both Ga1 and Ga2 crossing barriers. Once induction ability is determined, the best families will be selected for a final increase and testing in summer 2025, and made available for release from fall 2025 on. Development of sweet corn carrying SHGD: We continued the efforts to introgress the SHGD trait from A427 into different sweet corn backgrounds. BC2 derived haploids in the background of for example Wh17066V showed restored fertility in clearly more than 50% of the haploids, indicating, that this background per se might already have the ability to spontaneously double. New backcrosses (BC3) and BC2-derived DH lines were generated in different backgrounds. As major genes are being incorporated at Wisconsin, we have begun to test DH lines generated through program in hybrid combinations. Hybrids were evaluated in Madison in 2024 and some are very promising Development of specialty corn varieties: We continued to work with the haploids generated in materials provided by Paul Scott in summer 2024. On average 60 haploids per induced rows were established in the field after rouging out false positives, about 25% showed restored male fertility and self-pollination was attempted. About 90 DH lines could be generated, half of them with 10 kernels or more. They are returned to Paul Scott for further evaluation. The Scott group continued development of two specialty corn varieties using the DH technology described in the proposal. The first is designed to be used for production of highly digestible forage and contains the major genes o2/bm3/SHGD and Ga1 and the second is designed to produce high value waxy starch and contains the major genes y1/wx/SHGD and Ga1-S. All major genes were combined in F1 crosses which were induced last year. This year, we are selecting individual plants containing the desired gene combinations. Objective 3: On farm trials Scott: A population of high-methionine corn was grown on the farm of Travis Otto in Cherokee, Iowa. Some lodging was observed following a strong wind storm, but the plants recovered fully and all ears were harvestable. Delate: Field plot design and data collection plans for the 2023 on-farm corn variety trials were finalized via email with farmer-cooperators in February 2023. Results from the 2023 field corn season on four farms in Iowa (SW1, SW2, NC, NW) were impacted by drought. Despite the harsh weather, high yields were achieved across all farms, with no statistical yield differences between varieties. The overall average corn yield across all varieties and across all farms was 174 bu/acre. The ranking of yields was as follows: Prairie Hybrids 5141 (Deer Grove, IL) at 178 bu/acre; Blue River O.18-06UP (Albert Lea Seed, Albert Lea, MN) at 173 bu/acre; Blue River 46-02 at 165 bu/acre; Blue River 62G22 at 159 bu/acre; Blue River 54PM37 at 155 bu/acre; and Prairie Hybrids 4211 at 152 bu/acre. The USDA varieties yielded 128 bu/acre in the 19SJWE and 126 bu/acre in the 22SJWE. At the research farm site in Greenfield, IA, the organic corn yields in the longest crop rotation sequence (C-S-HR/RC-RC) averaged 187 bu/acre, compared to the conventional yields of 123 bu/acre. Corn protein levels showed no significant differences across varieties, averaging 6.4%. Corn density averaged 1.27 g/cc. Corn starch averaged 62.17% across varieties. Oil content averaged 3.58% across all varieties with no significant differences between varieties. Corn ear weight in the 2023 trial averaged 233 g/ear across the trial with no statistical differences between varieties, with the BR 54C27 numerically greater, at 248 g/ear. Kernal weight per ear averaged 207 g/ear across the trial, with PH 5141 kernel weight numerically greater, at 222 g/ear. Ear length ranged from 7.37 inches to 8.48 inches. Disease and damage ratings were relatively low across farms and varieties, averaging less than 1% of ear damage across all farms and varieties. In 2024, corn varieties that were tested across the 4 farms (NC, NW, SW1 and SW2) included PH 5141 and PH 3051 (Prairie Hybrids, Deer Grove, IL), Blue River O.18-06UP (Albert Lea Seed, Albert Lea, MN), and BR 84-04, BR 46-02 and BR 85-09 (Albert Lea Seed, Albert Lea, MN). On the SW farm, Miller Hybrids (Miller Hybrids, Kalona, IA) varieties M10-54, M11-66, and M14-81 were grown. No USDA hybrids were grown in the trial in 2024 due to seed unavailability. Corn was planted across the four sites between May 17 and June 6, 2024. Plant emergence across the four on-farm sites ranged from 27,055 plants/acre at the NC site to 34,370 plants/acre at the SW2 site. Broadleaf weed populations were managed well in 2024 across all sites with averages of 0 weed/m2 at the NW site to 5 weeds/m2 at the SW2 site. Grass weeds averaged 9/weeds/m2 across all farms, and were greatest at the SW1 farm, at 29/weeds/m2, compared to 0/weeds/m2 at the NW site. Publications Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Dermail, A., L&#65533;bberstedt, T., Suwarno, W.B., Chankaew, S., Lertrat, K., Ruanjaichon, V., Suriharn, K. (2024) Haploid Inducer by Source Germplasm by Season Interaction on Tropical Maize Using GGE Biplot and Stability Analysis. Agronomy 14, 1505. Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Foster, T., Kloiber-Maitz, M., Gilles, L., Frei, U.K., Pfeffer, S., Chen, Y.-R., Dutta, S., Seetharam, A., Hufford, M., L&#65533;bberstedt T. (2024) Fine-mapping of a major QTL for spontaneous haploid genome doubling (qshgd1) in maize. Theor. Appl. Genet. 137:117 Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Chen, Y.-R., Frei, U.K., L&#65533;bberstedt, T. (2024) Genomic Estimated Selection Criteria and Parental Contributions Increase Genetic Gain of Maternal Haploid Inducers in Maize. Theor. Appl. Genet. 137: 248 Progress 09/01/22 to 08/31/23 Outputs Target Audience:Organic farmers, Organic organizations, Plant breeders, Seed producers, Seed processors Changes/Problems:U Wisconsin (Tracy) How has COVID impacted the work planned for this reporting period? COVID issues linger especially in the areas of travel for research purposes and especially hiring hourly works. Brief description of any other problems/changes/weather impacts encountered over the last

reporting period. Severe drought affected most of the field operations. We were able to access irrigation and most research objectives were attained USDA-ARS (Scott) Since our initial screen for four-gene combinations in the specialty corn breeding program was not successful, we will be repeating this screen with larger numbers of individuals. What opportunities for training and professional development has the project provided?Two Ph.D. students are currently involved, Mercy Fakude (Lubberstedt) and Tae-Chun Park (Scott). Wisconsin Ph.D. student Carl Branch managed the SHGD nursery in Madison, where he made numerous backcrosses to the appropriate parents. Those backcrosses are now growing in Chile in preparation of further backcrossing and selfing. Tae-Chun Park is a second year Ph.D. candidate in the Interdepartmental Plant Biology Program at Iowa State University. He was trained in developing molecular markers for major genes used in this project. In addition, the Scott group trained student interns (e.g., Hannah Clubb) in field operations and seed inventory management. Lubberstedt hosted an intern (Thalia Ramos) from University Puerto Rico Mayaguez, a Hispanic Serving Institution. Robert Turnbull and Josiah Pollock (Extension Program Specialists) were trained in on-farm experimental protocols and data analysis for this project (Delate). How have the results been disseminated to communities of interest?Co-PI Delate is organizing the annual Iowa Organic Conference, where project participants Lubberstedt and Fakude participated in 2022, and will together with co-PI Scott participate in 2023. For 2023, a lunch session with stakeholders is planned. Co-PI Delate organized an field event in August of 2023, with participation from farmers and presentations by co-PI Scott and Dr. Frei on haploid induction and the doubled haploid process. Lubberstedt, Scott, and Fakude visited Iowa organic farmers along with other students in July of 2023 (Rossmann, Skye farms). Lubberstedt visited Beck\'s Hybrids in Marshalltown. Lubberstedt presented ACES and CoMGI in person at the annual OREI program meeting in Washington DC. Lubberstedt, Scott, Tracy, and Delate as well as students have been actively participating with oral or poster presentations in various meetings and conferences in 2023 (ASTA, CSSA, R.F. Baker Symposium, Maize Genetics Conference, NAPB, Iowa Organic Conference, among others). Event Paul Scott gave a presentation at the University of Missouri, Columbia entitled \"Breeding Corn for Organic Production Systems\" November 14, 2022. Product Press release by ARS News Service, \"Scientists ratchet up key amino acid in corn\" September 28, 2023, https://content.govdelivery.com/accounts/USDAARS/bulletins/372a2e6 Event Paul Scott discussed this project at the Iowa Organic Association Field day, September 7, 2023, Wesley Iowa Event Paul Scott and Ursula Frei discussed this project at the Shriver farm field day, August 1, 2023, Jefferson, Iowa, 51 participants Event Branch, Carl A. The sugary enhancer1 (se1) allele is associated with significant decreases in the amount of lutein, zeaxanthin, and tocotrienols in yellow (Y1) sugary1 (su1) kernels. Vegetable Breeding Institute Cornell University August 2023 Event Tracy, W.F. Wisconsin Sweet Corn Update. Midwest Food Products Association, Wisconsin Dells. November 2022 Event Tracy, W.F. Wisconsin Sweet Corn Update. Vegetable Breeding Institute Cornell University August 2023 Event Lubberstedt, T. Presentation of USDA ACES project at annual USDA OREI PI meeting in Washington D.C. in April 2023 Event Lubberstedt, T. Invited Presentation \"Efficient breeding of resilient crops using doubled haploid technology\" at R.F. Baker Symposium at ISU, Ames IA in March 2023 What do you plan to do during the next reporting period to accomplish the goals?Objective 1: Completing publication on Functional Markers. Improve molecular markers for wx, Y1, SHGD, and BM3. Objective 2: Evaluation of Ga2 inducer candidates Sweet corn DH line development, carrying SHGD Continue incorporation of desirable alleles into sweet corn DH material. Investigate the extent within sweet corn germplasm of the ability to overcome pollen exclusion conferred by Ga1 and Ga2 Specialty corn: Screen for individuals with desired gene combinations Objective 3: Continuation of on farm field trials in 2024, as described above for 2022 and 2023. Impacts What was accomplished under these goals? Impact statement: This proposal outlines a plant breeding approach that facilitates combination of independent genetic loci in breeding programs. This approach will impact breeding programs focused on production of organic specialty corn varieties, which often require multiple genetic loci to create a desired product. The ability to produce improved varieties faster benefits the public by making products made from the improved varieties less expensive to make, higher quality, and safer while reducing negative impacts on the environment. Objective 1: Functional marker development Functional marker development has been completed. Each group has marker assays available as needed - or receive help from other groups with genotyping as needed. Tae-Chun Park is working on a review paper on functional markers, and is interacting with a distance MS in Plant Breeding student, who is preparing a Creative Component (CC) on this topic. Both publication and CC will be published in the upcoming project year. Objective 2: Use of breeding strategies including DH technology for efficient transfer of major genes or QTL into elite germplasm Development of a Ga2 haploid inducer: The Ga2 haploid inducer development was continued during the winter 2022 and summer 2023 season. Induction ability of the families was tested on a conventional hybrid (Viking 51-95UP, Albert Lee Seed, MN) and individual plants within the families were tested for their ability to overcome the Ga2 crossing barrier. We will continue with four families with the Ga2 allele present and induction abilities of 12, 13, 14, and 19% in the conventional hybrid respectively. Two of the families also showed the ability to overcome the Ga1 crossing barrier. First induction crosses in materials heterozygous for the Ga2 allele (provided by Paul Scott) were performed in summer 2023 - haploid selection has not been started yet. Development of sweet corn carrying SHGD: ISU is helping with inductions, and conducts a parallel backcross program of fertile haploids,

used to create the next backcross generation. This will serve as back-up to marker-assisted backcrossing. We (Tracy and team) continued to backcross DH lines for identification and incorporation of desired alleles. We investigated issues presented by the frequency of alleles in sweet corn that can overcome the Ga1 and Ga2 crossing barriers. Development of specialty corn varieties: A challenge to developing specialty corn varieties is that some products require combining multiple unlinked genetic loci. This proposal outlines a combination of technologies that improves this process. Using the process described in the proposal, USDA-ARS is developing two types of specialty corn varieties. Corn for organic silage is being developed by combining the mutations o2, bm3, Ga1-S and SHGD. This corn will produce silage with highly digestible grain and vegetative tissues, will have added genetic purity, and will be amenable to improvement by breeding. High value corn production of high value organic specialty starches is being developed by combining the mutations y1, wx1, Ga1-S and SHGD. This corn will have white waxy kernels, with improved genetic purity, and will be amenable to improvement by breeding. These traits are valued by the organic food industry for making specialty starches and food additives. In the 2023 summer field season, we screened for fertile individuals containing all the desired mutations. This screen was not successful and will be repeated next season with larger numbers to ensure success. Objective 3: On farm trials ?In 2022, there were significant differences in corn yields between the NE farm, with excellent rainfall, compared to NC, NW and SW farms, due to the drought. The overall average corn yield across all varieties and across all farms was 185 bu/acre. There were no statistical differences among varieties when averaged across all farms, but there were numerical differences worth noting. The ranking of yields across all farms was as follows: PH 5141 (Prairie Hybrids, Dear Grove, IL) at 201 bu/acre; Blue River 62G22 (Albert Lea Seed/Blue River, Albert Lea, MN) at 191 bu/acre; PH 4211 and Viking O.18-06 at 189 bu/acre; BR 54PM37 at 182 bu/acre and Viking O.48-08 at 155 bu/acre. The USDA varieties averaged 108 bu/acre. There was quite a variation of corn moisture at harvest with the NE farm averaging 22% compared to the SW farm averaging 14%. In 2023, corn varieties that were tested across the 4 farms included: PH 5141 (Prairie Hybrids, Dear Grove, IL); Blue River 54C27 (Albert Lea Seed/Blue River, Albert Lea, MN); PH 4211 and Viking O.18-06; BR 54PM37 and Viking O.46-02. The USDA hybrids were only tested at the NC farm. Corn was planted across the four sites between May 17 and May 23, 2023. An OREI Organic Corn Variety Field Day was held on August 1, 2023, at the Shriver Farm, in Jefferson, IA, with 51 participants. As of this date, not all corn has been harvested due to wet weather. We will repeat this trial in 2024. Publications Type: Journal Articles Status: Published Year Published: 2023 Citation: Trentin, H.U., Yavuz, R., Dermail, A., Frei, U.K., Dutta, S., L&#65533;bberstedt, T. A comparison between inbred and hybrid maize haploid inducers. Plants 12:1095 https://doi.org/10.3390/plants12051095 Type: Journal Articles Status: Published Year Published: 2023 Citation: Aboobucker, S.I., Zhou, L., L&#65533;bberstedt, T. Haploid male fertility is restored by mutations in parallel spindle genes in Arabidopsis thaliana. Nature Plants 9:214-218 10.1038/s41477-022-01332-6 Type: Journal Articles Status: Published Year Published: 2023 Citation: Aboobucker, S.I., L&#65533;bberstedt, T. A genetic mechanism to restore haploid male fertility in Arabidopsis an alternative to chemical methods. Nature Plants 9:205-206 https://doi.org/10.1038/s41477-022-01335-3 Type: Journal Articles Status: Published Year Published: 2023 Citation: Dermail, A., Chankaew, S., Lertrat, K., Suwarno, W.B., L&#65533;bberstedt, T., Suriharn, K. Combining ability of tropical x temperate maize inducers for haploid induction rate, R1-nj seed set, and agronomic traits. Frontiers in Plant Science 14:1154905. doi: 10.3389/fpls.2023.1154905 Type: Journal Articles Status: Published Year Published: 2023 Citation: Dong, D., Nagasubramanian, K., Wang, R., Frei, U.K., Jubery, T.Z., L&#65533;bberstedt, T., Ganapathysubramanian, B. Self-supervised corn kernel classification and segmentation for embryo identification. Frontiers in Plant Science 14:1108355. DOI 10.3389/fpls.2023.1108355 Type: Journal Articles Status: Published Year Published: 2023 Citation: Hintch, T., Lauter, A.M., Kinney, S., L&#65533;bberstedt, T., Frei, U.K., Duangpapeng, P., Edwards, J.W., Scott, M.P. Development of maize inbred lines with elevated grain methionine concentration from a high methionine population. Crop Sci. 63: 2417-2425. https://doi.org/10.1002/csc2.20983 Type: Journal Articles Status: Published Year Published: 2023 Citation: Ledesma, A., Aguilar, F.S., Uberti, A., Hufford, M., Edwards, J., Hearne, S., L&#65533;bberstedt, T. Haplotype sharing and diversity analyses of DH Lines derived from different cycles of the Iowa Stiff Stalk Synthetic Maize Population. Frontiers in Plant Sci. 14:1226072. doi: 10.3389/fpls.2023.1226072 Type: Journal Articles Status: Published Year Published: 2023 Citation: Trentin, H.U., Krause, M., Zunjare, R., Costa Almeida, V., Rotarenco, V., Beavis, W.D., V., Frei, U.K., L&#65533;bberstedt, T. Genetic basis of maize maternal haploid induction beyond MATRILINEAL and ZmDMP. Frontiers in Plant Science 14:1218042. DOI: 10.3389/fpls.2023.1218042 Type: Journal Articles Status: Published Year Published: 2023 Citation: Sanchez, D., Santana, A.S., Morais, P., Peterlini, E., De la Fuente, G., Castellano, M., Blanco, M., L&#65533;bberstedt, T. Genome-wide association analysis of doubled haploid exotic introgression maize (Zea mays L.) lines for agronomic traits under depleted nitrogen conditions. Frontiers Plant Sci. 14:1270166. DOI: 10.3389/fpls.2023.1270166 Type: Journal Articles Status: Published Year Published: 2023 Citation: Branch, C.A. & Tracy, W.F. (2023). Divergent selection for timing of vegetative phase change. Crop Science. 2023;19 Type: Journal Articles Status: Published Year Published: 2022 Citation: Colley, M.C., Dawson, J.C., McCluskey, C., Myers, J.R., Tracy, W.F., & Lammerts van Bueren, E.T. (2022). Exploring the emergence of participatory plant breeding in countries of the global North. The Journal of Agricultural Science. https://doi.org/10.1017/S0021859621000782 Type: Journal Articles Status: Published Year

Published: 2022 Citation: Colley, M.C., Tracy W.F., Lammerts van Bueren, E., Diffley, M., & Almekinders, C. (2022). How the seed of participatory plant breeding found its way in the world through adaptive management. Sustainability. 14 (2132), https:// doi.org/10.3390/su14042132 Type: Journal Articles Status: Published Year Published: 2023 Citation: Bapat, A. R., A. N. Moran Lauter, M. B. Hufford, N. A. Boerman and M. P. Scott, 2023 The Ga1 locus of the genus Zea is associated with novel genome structures derived from multiple, independent non-homologous recombination events. G3 Genes\|Genomes\|Genetics: jkad196. DOI: 10.1093/g3journal/jkad196 Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Delate, K. 2022. Participatory Organic Research: Methods to Enhance Farmer Researcher Partnerships, American Society of Agronomy Annula Meetings, Baltimore, MD, November 7, 2022: https://scisoc.confex.com/scisoc/2022am/meetingapp.cgi/Paper/145014 Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Fakude M, Frei UK, Foster TL, L&#65533;bberstedt T. Identification of genomic region associated with the causal QTL of SHGD trait in Ames panel by GWAS. The 64th Annual Maize Genetics Meeting. 2023 Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Fakude M, Frei UK, Foster TL, L&#65533;bberstedt T. Identification of genomic regions associated with the causal QTL of SHGD trait in Ames panel by GWAS. ASA-CSAA-SSSA. 2023 **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:Organic farmers, Organic organizations, Plant breeders, Seed producers, Seed processors Changes/Problems:Scott:We expanded the gene list of the specialty corn section of the project to include the bm3 mutation, which improves the quality of silage made from corn. This adds value to the project and takes advantage of existing project resources because we have already combined this gene with o2, a gene which is a target for this project. What opportunities for training and professional development has the project provided?Two Ph.D. students are currently involved, Mercy Fakude (Lubberstedt) and Tae-Chun Park (Scott). Moreover,Henry Franzen (undergraduate student) and Josiah Pollock (Extension Program Specialist) were trained in on-farm experimental protocols and data analysis for this project (Delate).Wisconsin Ph.D. student Carl Branch managed the SPDH nursery in Madison, where he made numerous backcrosses to the appropriate parents. Those backcrosses are now growing in Chile in preparation of further backcrossing and selfing. Tae-Chun Park is a second year Ph.D. candidate in the Interdepartmental Plant Biology Program at Iowa State University. He was trained in developing molecular markers for major genes used in this project. In addition, the Scott group trained three student interns (Hannah Clubb, Pedro Ramirez and Julio Roman) in field operations and seed inventory management. Two of these interns are from University Puerto Rico Mayaguez, a Hispanic Serving Institution. In addition, seven student interns from University of Puerto Rico Mayaguez were trained in corn nursery operations at our winter nursery site in Lajas, Puerto Rico. How have the results been disseminated to communities of interest?The National Association of Plant Breeders (NAPB) meeting was hosted at ISU in 2022 (Lubberstedt and Scott were co-hosts), which allowed to present products (field tour) and outcomes (posters) to a broad audience (close to 400 participants). Field Days and conference presentations were utilized to disseminate information about the project.Organic vegetable field days were held in Madison WI in August 2022 and this project was discussed with attendees there. We continue to have buy-in from project farmers to grow the specific varieties or lines, and assist with data collection during the season. This shows great promise for their continued involvement in evaluating new lines that are developed from the ACES pipeline, which is the predecessor of CoMGI. Paul Scott presented a seminar in the Interdepartmental Plant Biology seminar series at the University of Missouri, \"Breeding corn for organic production systems\". Columbia, Mo, November 14, 2022 (not sure if this in the period of performance) Paul Scott presented a seminar in Plant Biology 696, Iowa State University, \"Cross Incompatibility in Corn\". Ames, Iowa, September 29, 2021. (not sure if this is in the period of performance) Paul Scott was invited to provide information on gametophyte factors to representatives of the popcorn and seed corn industries in two meetings organized by the American Seed Trade Association December 8, 2021. What do you plan to do during the next reporting period to accomplish the goals? Marker and plant material development will continue as planned. Delate: Hybrids from germplasm developed under the 2014 NIFA - OREI grant, and any germplasm that becomes available from this OREI grant, will be tested in organic farmer-cooperators' fields. Sweetcorn germplasm from UW's program will also be tested. We will make crosses among plants carrying two or more of the major genes that are targets in the specialty grain section of this project to create populations in which 4 desired major genes are segregating. These populations will be induced to create haploids and individuals containing all four genes will be identified. **Impacts** What was accomplished under these goals? (i) Functional marker development and application: Functional marker development is ongoing, with some of the markers being available. Moreover, we did meet with Eurofins, and will consider their involvement for more efficient marker development and genotyping work. (ii) Use of breeding strategies including DH technology: Development of a Ga2 haploid inducer: The current set of haploid inducer lines cannot pollinate breeding materials that have the Ga2-S locus incorporated, to prevent unintentional pollination by (transgenic) dent corn. The introgression of the Ga2-S allele started already in winter 2021 using haploid inducing lines developed in the backgrounds of B73, Mo17 and PHG83. Haploid inducer lines that have the Ga1-S allele were not able to pollinate the Ga2-S donor lines and vice versa with the exception of one Mo17 derived inducer line. Mo17 is known to be able to overcome the crossing barrier of Ga2 and opens thus for the

possibility to develop an inducer line that can be used in both Ga1 and Ga2 backgrounds. During the summer 2022, BC1:F2 and BC2:F1 families were tested for their ability to pollinate the Ga2-Tester as well as the Ga1-Tester. As expected some inducer lines with Mo17 their genetic background were able to pollinate both tester. Ear to row in the selected inducer families will continue, test pollinations to determine the induction ability of the inducer lines in different genetic backgrounds are planned. (iii) On farm trials: In 2022, six commercial organic field corn varieties: BR 54PM37, BR 62G22 (Blue River, Ames, IA), Prairie Hybrids 4211, Prairie Hybrids 5141 (Prairie Hybrids, Deer Grove, IL), Viking 0.18-06, and Viking 0.48-08 (Albert Lea Seed, Albert Lea, MN) were compared on four farms in Iowa (NE, NC, SW, NW), with one farm (NC) also evaluating USDA-bred hybrids. Viking 48-08 and PH 4211 tended to have the highest plant emergence, at 32,778 plants/acre and 32,500 plants/acre, respectively, but these were statistically equivalent to all other varieties. The USDA hybrids averaged 31,666 plants/acre, with the USDA 7675 hybrid averaging 32,666 plants/acre. Regarding weed populations, often reflective of corn shading potential, the USDA 5812 hybrid had the highest number of broadleaf weeds at 6 per square meter, compared to an average of 1 weed per square meter for all commercial varieties. Viking 48-08 and PH 4211 tended to have the lowest number of broadleaf weeds, averaging 1 weed per square meter. Grass weeds were less prolific, averaging 1 weed per square meter across all varieties, with no statistical differences. The tallest varieties were BR 62G22 and Viking 48-08, at 276 cm and 261 cm, respectively, but there were no statistical differences among varieties. THE USDA varieties averaged 238 cm overall, with USDA 7681 the tallest, at 248 cm. The BR 54PM37, PH 5141, and Viking 18-06 varieties tended to produce more than 1 ear per plant, but there were no statistical differences among varieties. Insect populations (corn borer, aphids, other pests) were low in 2022, averaging damage ratings of 1 or lower, with no statistical differences among varieties. Disease incidence was also low in 2022, with no differences in ratings among varieties. USDA hybrids showed low insect or disease incidence. Yields will be correlated with pest incidence when all yields are determined. **Publications** - Type: Journal Articles Status: Published Year Published: 2021 Citation: Verzegnazzi, A., Santos, I., Frei, U.K., Krause, M., Campbell, J., Almeida, V., Tonello Zuffo, L., Boerman, N., L&#65533;bberstedt, T. (2021) Major locus for spontaneous haploid genome doubling detected by a case-control GWAS enables efficient doubled haploid line development in exotic maize germplasm. Theor. Appl. Genet. 134: 1423-1434 DOI: 10.1007/s00122-021-03780-8 - Type: Journal Articles Status: Published Year Published: 2022 Citation: Trampe, B., Batiru, G., Pereira, A.S., G., Frei, U.K., L&#65533;bberstedt, T. (2022) QTL mapping of inducibility using genotype by sequencing in maize. Plants 11: 878 DOI 10.3390/plants11070878 - Type: Book Chapters Status: Published Year Published: 2022 Citation: Muhammad-Aboobucker, S., Jubery, Z., Frei, U.K., Foster, T., Chen, Y.-R., Ganapathysubramanian, B., L&#65533;bberstedt, T. (2022) Protocols for in vivo doubled haploid (DH) technology in maize breeding: From haploid inducer to haploid genome doubling. Methods Molecular Biology, Plant Gametogenesis, Methods and Protocols (C. Lambing ed.) 2484: 213-235 https://doi.org/10.1007/978-1-0716-2253-7_16 - Type: Journal Articles Status: Published Year Published: 2022 Citation: Trentin, H.U., Batiru, G., Frei, U.K., Dutta, S., L&#65533;bberstedt, T. (2022) Investigating the effect of the interaction of maize inducer and genome backgrounds on haploid induction rates. Plants 11:1527, https://doi.org/10.3390/plants11121527 - Type: Journal Articles Status: Published Year Published: 2022 Citation: Santos, I., Verzegnazzi, A.L., Edwards, J., Frei, U.K., De La Fuente, G.N., Zuffo, L., Pires, L.P.M., L&#65533;bberstedt, T. (2022) Usefulness of adapted exotic maize lines developed by Doubled Haploid and Single Seed Descent methods. Theor. Appl. Genet. 135, 1829-1841, https://doi.org/10.1007/s00122-022-04075-2 - Type: Book Chapters Status: Published Year Published: 2021 Citation: Boerman N.A., Lauter A.N.M., Edwards J.W., Scott M.P. (2021) Variation in degree of pollen exclusion for ga1-s unilateral cross incompatibility in temperate maize breeding populations, Agrosystems, Geosciences & Environment, John Wiley & Sons, Ltd. pp. e20220.

↑ Return to Index

A Multi-state Approach for Assessing the Needs of Postharvest Practices in Order to Improve Quality and Safety of Organic Produce

Accession No.	1026726
Project No.	KS10211198
Agency	NIFA KAN\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34915
Proposal No.	2021-02966
Start Date	01 SEP 2021
Term Date	31 AUG 2022
Grant Amount	$49,586
Grant Year	2021
Investigator(s)	Pliakoni, E. D.; Mitcham, EL, J.; Brecht, JE, .; Shoemaker, CA, A.; Nwadike, LO, .; Rivard, CA, .; Bhullar, MA, SI.; Deltsidis, AN, .

NON-TECHNICAL SUMMARY

This planning project will engage a diverse group of organic growers, grower organizations, buyers and consumers to identify the critical needs for organic produce postharvest handling research, education, and extension in the US. The identified critical needs will then be utilized to develop an integrated-multiregional project proposal to the OREI program. We will do that by:(1) forming a Multistate Advisory Panel (MAP) which will involve organic produce growers and buyers, extension, research and teaching faculty from all five states involved. This MAP will provide overall guidance to this planning project; (2) developing and disseminating an organic produce grower and buyer questionnaire (needs assessment) with the engagement of the MAP which will help identify critical needs for research, education and extension in postharvest handling and food safety practices for organic produce; (3) conducting focus groups with stakeholders to further understand and prioritize the postharvest challenges of organic produce growers and buyers; (4) sharing the key information from the needs assessment with all stakeholders through dissemination modes; and (5) developing the full integrated-multiregional proposal by incorporation of all the collected input.This project will address the following program goals: facilitating the development and improvement of organic agriculture production, breeding, and processing methods; evaluating the potential economic benefits of organic agricultural production methods to producers, processors and rural communities; conducting advanced on-farm research and development that emphasizes observation of, experimentation with and innovation for working organic farms, including research relating to production, marketing, food safety, socioeconomic conditions and farm business management.

OBJECTIVES

The long-term goal of this project is to provide small-acreage organic produce growers with appropriate postharvest handling practices that they can use to ensure the quality, shelf-life and safety of their products.This planning project effort will be focused on the following objectives: (1) We will form a Multistate Advisory Panel (MAP) which will involve organic produce growers, grower organizations, produce buyers, and extension, research and teaching faculty members. This MAP will be engaged in all project planning activities and will provide their inputs to direct the project.(2) We will develop and disseminate organic produce grower and buyer surveys (needs assessment) with the MAP, to help identify critical needs for research, education and extension in

postharvest handling for safe and high quality organic produce.(3) We will conduct focus groups with organic growers, grower organization leaders, buyers, and consumers, which will help us understand and prioritize their challenges.(4) We will share the key information generated from the needs assessment with all stakeholders through various vehicles of dissemination.(5) We will engage and incorporate the inputs and recommendations of all groups in developing the integrated multistate organic postharvest practices project proposal.

APPROACH

MethodsSurvey methodology will be based on the Dillman Method (2014) and focus groups will incorporate the Krueger and Casey (2000) approach to effective qualitative research and Graffinga and Bosio (2006) guidance on conducting online focus group discussions. The focus groups will be strategically designed and implemented to document and obtain feedback from our stakeholders regarding the questionnaire results. Organic growers and/or buyers questionnaire. The initial survey of our stakeholders will be done through an online questionnaire. Research has shown that electronic surveys are the fastest growing form of surveying across the US and they can generate information quickly and at a low cost (Dillmanet al., 2014).The online survey will be distributed in Kansas, Missouri, California, Georgia, and Florida and activated December 2021 to February 2022. The survey will be disseminated to growers through social media, email listservs, and websites and will be directed specifically to groups such as Growing Growers KC, the Kansas Specialty Crop Growers Association, the Kansas Rural Center, the MidAmerica Organic Association, the Great Plains Growers Conference, Florida Organic Growers, Georgia Organic, California Certified Organic Farmers, EcoFarm Conference in California and others. Focus groups. We are planning to utilize online focus groups (OFG) since we need to be able to connect participants from all five states involved in this project. There are two main approaches for conducting online focus groups: synchronous and asynchronous groups. Research has shown that a combination of both allowed for detailed discussion during the asynchronous groups while also getting a broad and encompassing discussion in the synchronous discussion (Graffinga and Bosio 2006). We are planning to hold focus groups discussions of 6-8 participants in the five states from March 2022 to May 2022 in order to delve deeper into the specific needs of each state regarding postharvest handling of organic produce. Focus group discussions with some multistate groups will help us identify broader issues that the organic growers and buyers are facing. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:This project was conducted to identify research, education, and extension priorities that will address the challenges organic growers and buyers face regarding postharvest handling practices. A national questionnaire was distributed to organic produce growers to better understand current postharvest practices, postharvest loss issues, and barriers to adopting or improving food safety and postharvest practices. A similar questionnaire was also distributed to industry buyers of organic produce to understand their buying patterns, postharvest loss issues, and to identify problems within the supply chain of organic produce. It was also an objective to identify how growers and buyers want to receive technical information and education. The questionnaire generated 68 responses from growers and 35 responses from industry buyers, which was lower than our target sample sizes of 96 responses from organic growers and 97 responses from industry buyers. Focus groups were also held with 8 organic produce buyers to further understand their challenges in regards to food safety and postharvest handling. Changes/Problems:The biggest challenge that we have to report is the questionnaire responses we generated 68 responses from growers and 35 responses from industry buyers, which was lower than our target sample sizes of 96 responses from organic growers and 97 responses from industry buyers. What opportunities for training and professional development has the project provided? We train one post-doctoral associate How have the results been disseminated to communities of interest?The results have been disseminated: A proceedings manuscript has been submittedtotheUrban Food SystemsSymposium 2022 (UFSS 2022); An oral presentation was presented in 2022 in theoral section: food security and safety with the title: Identifying challenges in the postharvest supply chain of fresh organic produce in September 2022; A summary of the results was also presented at the Olathe Horticulture Research and Extention Center during the commercial field day in August 2022. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? 1. We formed a Multistate Advisory Panel (MAP) consisting of15 individuals that represented organing growers and buyers from all 4 states. 2. Two separate nationally-distributed questionnaires were made for our two target demographics: organic growers of fresh produce and industry buyers of fresh produce. The questionnaires were developed with the project PI's input from our MAP. The questionnaire consisted of demographic questions as well as short answer, multiple choice, and rank questions to answer our objectives. The objectives of the questionnaire were to: Identify the degree of willingness of organic growers/processors/distributors to apply?specific postharvest practices and technologies. ? Determine the barriers farms are facing in implementing or improving?postharvest handling and food safety practices. Determine organic growers/processors/distributors preferences for receiving practical?information and support. Identify research gaps regarding produce safety and postharvest quality. The questionnaire was conducted anonymously and electronically through Qualtrics from January 10th, 2022,through February 28th, 2022.

Advertisements for the survey were done through appropriate farming-based email listservs and organic-focused conferences. For the buyer survey, we purchased a sponsorship with The Farm Journal to have the survey emailed to their audience of 77,000 produce industry stakeholders and advertised at the Global Organic Produce Expo Event from January 31st to February 2nd. To incentivize the questionnaire, a \$10 gift card was offered to all survey participants through the Rewards Genius Tango Card platform. The short answer questions were analyzed qualitatively by categorizing themes with NVivo software. To achieve a 10% margin of error and 95% confidence interval, the target sample size was 96 responses for growers and 97 responses from buyers. 3. Focus Groups Focus groups consisted of online asynchronous discussion boards and a synchronous zoom meeting with participants. Participants were recruited through the email list of individuals that completed our online questionnaire. The PI team chose topics to focus on for the focus group based on the results from the questionnaire. Prompts and discussion points used during the focus groups can be found in Table 1. Due to an inability to recruit enough participants from the industry buyer demographic, the focus group was only conducted with organic growers. The inclusion criteria for participation was: 1) They were growing fresh fruit, vegetables, or herbs and 2) They were NOP organic certified, planning to become certified, or not certified but using organic practices. The focus group began with a multi-day asynchronous online forum, where participants answered written prompts and commented on one another's posts. Focusgroupit.com was used to facilitate the online discussion forum and participants were given an anonymous username for posting. After the discussion board, participants were asked to answer a few short answer and multiple choice questions to capture farm demographic information and other relevant postharvest topics. The discussion board was followed by a 90-minute synchronous focus group over zoom. Discussion board and focus group transcripts were analyzed qualitatively by categorizing themes with NVivo software. Table 1. Organic grower focus group prompts and discussion points Online discussion board prompts Participants were presented with the results on the ranked barriers to adapting or improving postharvest handling practices (Figure 11) from the questionnaire and asked what their thoughts or reaction were to these results. We all know the importance of food safety and have a shared desire to keep consumers safe. How do you weigh the risk and rewards of implementing food safety practices and balancing that with produce quality in your farming and postharvest operation? Where do you find information about food safety and postharvest handling practices, including produce quality? What topics do you wish you could find more information on and how would that information benefit your farm? Synchronous focus group discussion points Participants were presented with the postharvest information needs of growers from the questionnaire and discussion board and asked if they agreed with the needs and if they had more to add. Decision-making processes in adopting new postharvest or food safety practices or changing your current infrastructure and processes.? Opinions/reactions to postharvest technology research topics Results summary: From the grower's perspective, the largest barrier they face is financial, which makes it difficult to invest in postharvest infrastructure and labor. A lack of knowledge was the second most important barrier to implementing or improving postharvest and food safety practices. Survey and focus group responses indicated that there is a need for postharvest handling information that includes low-cost options or return-on-investment data. Focus group participants agreed that food safety is of the utmost importance and critical for their business viability and customer's satisfaction. However, survey results showed that over one third of respondents were \"not sure\" if their farm was exempted from the Food Safety Modernization Act Produce Safety Rule, which could indicate a need for further education around farm food safety. Although the data is limited, buyers of organic produce indicated the largest barrier to increasing the supply of fresh organic produce is related to supply chain logistics. Respondents agreed that produce is often shipped under the optimum temperatures. However, labor shortages, driver shortages, and other supply inefficiencies are the currently the largest hurdles in the organic produce industry. Both buyers and growers indicated the best way for them to receive technical information is through websites or in-person demonstrations. The growers expressed problems finding reliable information online and thought a searchable website hub that contained reputable, variety-specific, and region-specific handling and shelf-life information would be useful to their operations. 4. A proceedings manuscript has been submittedtothe Urban Food SystemsSymposium 2022 (UFSS 2022); an oral presentation was presented in 2022 in the oral section: food security and safety with the title: Identifying challenges in the postharvest supply chain of fresh organic produce in September 2022. A summary of the results was also presented at the Olathe Horticulture Research and Extention Center during the commercial field day in August 2022. 5. The PIsmet at the beginning of August 2022 and developed a plan and an outline, including the survey and focused groups results and now additional we are in the processof recruiting team members and drafting the integrated multistate proposal. **Publications** - Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: Tricia Jenkins, Eleni Pliakoni, Londa Nwadike, Manreet Bhullar, Cary Rivard, Candice Shoemaker, Elizabeth Mitcham, Jeffery Brecht, Angelos Deltsidis. 2022. Identifying challenges in the postharvest supply chain of fresh organic produce. 2022 Urban Food Systems Symposium, Kansas City MO

↑ Return to Index

Integrating Hybrid Rye as a Winter Annual Crop Into Organic Pig Production.

Accession No.	1026668
Project No.	MIN-02-G09
Agency	NIFA MIN\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34894
Proposal No.	2021-02916
Start Date	01 SEP 2021
Term Date	31 AUG 2024
Grant Amount	$1,433,820
Grant Year	2021
Investigator(s)	Li, Y.; Lazarus, WI, F..; Johnston, LE, J..; Wilson, ME, .; Tallaksen, JO, .; Goplen, JA, .; Cox, RY, .

NON-TECHNICAL SUMMARY

Organic agriculture is a fast-growing segment in the U.S., with a 30% increase in sales between 2016 and 2019, reaching an all-time high of \$9.9 billion (USDA 2019). The number of organic pigs sold increased by 46% during this same period, demonstrating an increased demand for organic pork. Many farmers are interested in raising organic pigs. Pigs rely on high energy and high protein diets to achieve their genetic potential. Traditional feed ingredients that contain high energy and protein for pigs are corn and soybean meal. The price of organic corn and soybean meal has fluctuated 2 to 3 times that of conventional corn and soybean meal over the last five years. Since feed cost can contribute 65 to75% of the total cost of producing an organic pig, feed cost has a significant impact on profitability of organic pig farming. In addition, organic bedding, which is required for organic pig production, is rather costly due to the limited supply of organic straw in the U.S. One strategy to reduce feed and bedding cost is to integrate small grain crops into organic pig production systems. Diverse crop rotations and cover crops are essential strategies to manage soil health and control weeds in organic production. New hybrid varieties of cereal rye have become a more viable crop option for grain production in the Upper Midwest. Integrating hybrid rye into organic pig production will provide feed and bedding for pigs, while potentially reducing negative environmental impacts. In this project we will evaluate how hybrid rye, as a winter annual crop, influences the environmental impacts and economic viability of organic pig production. The goal of this project is to develop systematic strategies for reducing feed and bedding costs and facilitate organic farmers to adopt these strategies to improve production efficiency, reduce environmental impact, and sustain organic pig production in the Upper Midwest. Integrating hybrid rye as a winter annual crop into an organic pig/crop production system can potentially reduce cost of pig feed and bedding while simultaneously improving pork quality and reducing environmental impacts of organic pig production. We will achieve our goal by: 1) developing manure management strategies for optimizing productivity of winter hybrid rye, 2) Evaluating nutritional value of hybrid rye fed to pigs and determine its effects on meat quality, and manure characteristics of organic pigs, 3) Optimizing organic small grain and pig production systems that provide affordable feed and bedding to organic pigs while reducing environmental impacts, 4) Examining economic and environmental impacts of integrating hybrid rye into organic pig production systems, and 5) Facilitating organic farmers to adopt project outcomes by organizing field-days, workshops and seminars, and publishing short videos, fact sheets, extension articles and peer-reviewed scientific papers. Plot and pig trials will be conducted using certified organic land and facilities on the research farm of the University of Minnesota\'s West Central Research and Outreach Center. Our ultimate goal is to facilitate a sustainable organic pork production system in the Upper Midwest region of the U.S. and beyond.

OBJECTIVES

The overarching goals of this project are to: 1) develop systematic strategies for reducing feed and bedding costs in organic pig production and 2) facilitate farmers\' adoption of the strategies to improve production efficiency, reduce environmental impact, and sustain organic pig production in the Upper Midwest region. Integrating hybrid rye as a winter-annual crop into an organic pig/crop production system can potentially reduce the cost of pig feed and bedding while simultaneously improving pork quality and reducing environmental impacts of organic pork production. Specific Objectives Develop manure management strategies for optimizing productivity of winter hybrid rye for organic feed and bedding production Evaluate nutritional value of hybrid rye fed to pigs and determine its effects on meat quality and manure characteristics of organic pigs Evaluate regional production methods for organic feed and bedding, and develop alternative organic crop and pig production scenarios that incorporate small grains in organic crop rotations to provide a reliable, affordable supply of organic feed and bedding. Establish economic, soil, and life cycle assessment (LCA) models to examine the financial, soil, and environmental impacts of integrating winter hybrid rye into organic pig production, and alternative organic crop and pig production scenarios developed in Objective 3.Facilitate organic farmers to adopt project outcomes by organizing field-days, workshops and seminars, and publishing short videos, fact sheets, extension articles, and peer-reviewed manuscripts.

APPROACH

For Objective 1: Organic hybrid rye production and manure management strategies. To evaluate optimal nitrogen rates and sources for organically-produced hybrid rye, the experimental design for the small-plot field trials will include three different manure sources and four application rates (3 × 4 factorial) set up in randomized complete blocks with four replicates (blocks). The experiment will be repeated over two growing seasons in different organically managed fields. Manure will include raw and composted solid hog manure from an organic hoop barn production system and liquid manure from a conventional hog finishing production barn. Application rates for each manure source will include 0 N (control) and 90, 135, and 180 kg ha-1 of first-year N. Stand counts and biomass collections will occur in the fall following rye establishment to determine if manure source or rate have an effect on rye establishment. Grain yield, moisture, and quality will be determined at harvest when the center of each plot is harvested and subsampled with a plot combine. In addition to the study area, thirty acres of organic land will be used over two years in parallel to the small plot study to produce the hybrid rye required for the feeding trials. For Objective 2: Replace corn with hybrid rye in pig diets and evaluate effects on growth performance, carcass and meat quality, and manure characteristics of organic pigs. Pig trials will be conducted using the certified organic swine research facility at the WCROC. All pigs will be managed according to the organic standards set by the National Organic Program (NOP). There will be two dietary treatments imposed onto pigs: control diet vs. treatment diet with hybrid rye replacing 50% of the corn in the control diet. A randomized complete block design will be used. There will be five blocks at 10-week intervals, using 80 sows and 500 pigs for the entire project. Within each block, 100 healthy pigs (9 wk old) will be transferred to two pens in a hoop barn. One hoop barn will house a control group and a treatment group side-by-side. Growth performance data (feed intake, average daily gain, feed efficiency, morbidity and mortality) will collected until pigs reach the market weight. Organic pork produced per acre of land will be calculated based on rye yield (kg/acre) along with nutrient composition of rye and pig performance data (kg of body weight gain).Nitrogen and P concentrations in manure from pigs between control and treatment pens will be compared to verify whether diets with hybrid rye will reduce P excretion and improve the N:P ratio for crop utilization. Fecal samples will be collected from 10 pigs randomly selected in each pen for analyses of Phytate-P, and total N and P concentrations. To evaluate carcass traits and meat quality, 8 gilts from each pen will be harvested for evaluation of carcass and meat quality. Water holding capacity (an indicator of juiciness) will be measured by chill loss, purge loss, and cooking loss. The subjective and objective color of pork chops will be used as one of the indicators for consumer acceptance. The Warner-Bratzler shear will be used to evaluate toughness of pork chops. Consumer taste panelists will be recruited based on age, gender, and experience with eating pork. Panelists will be asked to taste and rate pork samples for intensity of off flavor, juiciness, and toughness on separate 20-point line scales (AMSA 1995). For Objective 3: Evaluate current situations and design alternative cropping and swine production scenarios We will examine recent research and extension publications, professional group recommendations, and suggestions from agronomy researchers and organic stakeholders for small grain and swine production. The data collected will include all inputs to the production process, including seed, manure, fuel, equipment, irrigation resources, and harvest inputs. The primary output of grain/straw (yield and quality) and swine (meat production) will also be collected along with relevant data economic and environmental impacts.For Objective 4: Soil, LCA, and Economic modeling Two farm-based models will be examined for their ability to predict carbon changes in

organic cropping. The Integrated Farm Management Systems (IFMS; Rotz et al. 2011) and the Comet model (Comet Farm 2020) are both process driven models that use crop management strategies, regional climate factors, and production data to estimate soil carbon and greenhouse gas changes to farmland. While both models have the underlying data to predict changes due to production of specific crops, neither is specific for organic cropping and there will likely need to be some adjustments made to input data to properly simulate some organic cropping/management combinations. LCA Modeling will use attributional LCA methodologies to compare the current organic production systems and identify important factors for environmental impacts and organic standards that influence productivity under the scenarios studied. The primary impacts measured will be the greenhouse gas emissions and fossil energy, and land use, but the team will also begin collecting data, where available, on water quality (eutrophication), and water use (irrigation/extraction) for the scenarios examined. In examining crop rotations, we will evaluate a number of possible functional units (possibly impacts per kg grain equivalent or starch calories or net energy) to understand how the choice of functional units affects findings based on the multiple outputs of the organic system. Economic modeling component of this project will center on three tasks, 1) developing spreadsheet templates that are appropriate for rye production scenarios, 2) collecting external data needed to model the scenarios, and 3) running the models and examining how the methods identified in those scenarios impact economic returns for the systems being examined.The first step is consulting with the project team and reviewing the relevant modeling scenarios to identify practices and constraints on the systems that impact financial modeling decisions. This information will be used to construct a spreadsheet model looking at the economics of including a small grain such as rye in a typical Minnesota crop operation. The enterprise budget models for rye and other crops will be detailed analyses to demonstrate differences among production methods being studied, including crop rotation suitable for an organic farm with or without rye.For operating crop budget models, we will use input and output data generated from farm business summaries and extension recommendations to develop specific crop enterprise budgets for rye as well as the rotational crops being studied. Additional crop cost and return summaries from FINBIN and other farm business models will be used where needed as background data (FINBIN, 2019). Machinery ownership and operating costs will be based on extension reports based on engineering methods, and on custom rate surveys. Crop enterprise budget models organize yield, price, and cost information to compare profitability to suggest which crops and practices producers should adopt and likely will adopt over time.For Objective 5: Facilitate organic farmers to adopt project outcomes. Facilitating organic farmers to adopt project outcomes is a major focus of the project. Throughout the project period, we will disseminate outcomes of the project to stakeholders using a variety of methods, including: field days, workshops, seminars, presentations at conferences, and publications via extension websites, social media, newspapers, popular magazines, peer-reviewed scientific journals, and publicly available databases. Progress 09/01/23 to 08/31/24 Outputs Target Audience:The main audience for this project is organic farmers and their stakeholders, including organic certifiers, organic product marketers, as well as researchers, agricultural professionals, and extension specialists. Outcomes of the project have been disseminated to the audience through field days, presentations at farmer meetings and conferences, and publications in proceedings, magazines, newsletters, websites, and other social media. Changes/Problems:This project has been approved for one year no-cost extension due to the delay in organic pig feeding trials. Due to the delay in data collection from the swine trials, data needed for the LCA and economic modeling were not available during the past reporting period. Consequently, work to achieve Objectives 3 and 4 has been delayed. However, the delays will not impact on us completing the project. We will complete all the remaining work as proposed in the proposal over the final reporting period. What opportunities for training and professional development has the project provided?The project provided educational and training opportunities for graduate students. Two graduate students continued to collect data from the project for their theses and disseminated outcomes of the project to both academic and farmer communities. Through the project, the graduate students were trained to present scientific information to large audiences of different stakeholders (farmers, industry collaborators, extension specialists, and scientists). Additionally, the students created an extension video to demonstrate tips for successful organic pig farming. The project also provided professional development for the team to attend regional and national conferences to interact with organic farmers and their stakeholders and disseminate outcomes of the project. How have the results been disseminated to communities of interest?Results have been disseminated to organic farmers, organic certifiers, industry partners, agricultural professionals, extension educators, researchers, and legislators through presentations, demonstrations, and discussion at organic conferences (MN Organic Conference and Marbleseed Conference), academic conferences (Midwestern ASAS and National ASAS), field days (Organic Swine Field Day and Organic Crops Day), workshop of the Forever Green Initiative, University of Minnesota Extension/Outreach events (CFANS Research Symposium and Animal Science Showcase), as well as through publications in newspapers, newsletters, the university extension website, and other social media. Post event-evaluation was conducted which demonstrated that the outreach events were well received by organic farmers and their stakeholders. Participants were excited about outcomes of the project (e.g. organic hybrid rye can successfully replace 50% of corn in organic pig diet without negative impact) and indicated that they would share the information with others. What do you plan to do during the next

reporting period to accomplish the goals?The next reporting period will be the final period, and we will focus on publication of the project results and compile the final report. Objectives 1 and 2: We will complete statistical analysis of the data and submit/publish three papers to peer-reviewed journals. We also plan to present one or two abstracts at scientific conferences. Objective 3 and 4: Results from the updated model with the full organic swine production data set of the project will be added to the existing LCA model to produce the final project results. The economic model will also be revised with the complete organic swine and cropping system data. The soil, carbon, and economic models will be merged to develop recommendations for organic swine producers to enhance environmental and economic benefits of organic swine production. We will submit two manuscripts for publication in peer-reviewed journals. Objective 5: We will continue to publish factsheets and extension articles and disseminate outcomes of the project at farmer meetings and extension events. Impacts What was accomplished under these goals? Objective 1: We have completed all data collection for this objective, including data from the small-plot field trial and organic rye production on 17 acres over two years. Lab analysis of all samples have been completed, including soil and manure samples for N, P, K, pH, and organic matter, and rye grain samples for moisture content, test weight, and nutrition (protein) content. Currently, we are in the process of conducting statistical analysis of the data and preparing for publication in a peer-reviewed journal. Objective 2: Over the past reporting period, we completed all on-farm data collection by completing three replicates of the pig feeding trial. As in the previous two replicates, each replicate involved 100 pigs that were born to 16 sows in a deep bedded farrowing barn. Pigs were managed organically from prenatal (third trimester) to market weight (270 lb) according to the organic standards set by the National Organic Program (NOP). From 10 weeks old until market weight, pigs were fed control (organic corn soybean meal-based) or treatment (replacing 50% corn in the control diet with organic hybrid rye) diets. Control pens were bedded with organic wheat straw and treatment pens were bedded with organic hybrid rye straw. Organic hybrid rye grain harvested in 2023, and straw produced in both 2022 and 2023 were used for the three replicates of the feeding trial. Data collection was same as in the first two replicates, including growth performance (average daily gain, average daily feed intake, and gain to feed ratio) of pigs, samples of feed, bedding, manure packs, and feces for lab analysis, carcass traits (backfat thickness, loin area, and dressing percentage) and pork quality indicators (pH, shear force, water holding capacity, marbling score, and color). Feed samples were analyzed for proximates, fiber, and amino acid profiles for evaluation of nutritional value of diets. Bedding and manure samples were analyzed for moisture content, total N, organic N, P, and K for evaluation of fertilizer value. Additionally, feed and fecal samples were analyzed for total phosphorus and phytic acid to evaluate whether diets with hybrid rye may help pigs digest phosphorus. Currently, all data are subjected to statistical analysis and prepared for publications in peer-reviewed journals. Objectives 3 and 4: Cropping and soil simulations were conducted with different cropping combinations and rotations using the COMET model. Additional rotations and those already under consideration have been evaluated for their ability to build soil, form rotations acceptable to organic producers, and produce the needed rye crop. Crop and soil data were compared with existing literature on crop production. Life cycle assessment (LCA) modeling work related to swine production has been on hold due to the delay in data collection from organic swine production for the project. The best practice for LCA modeling is to do all analysis using the latest data and data in the literature from around the same period.Once the data analysis from Objective 2 is completed, we will update the COMET model with the complete organic swine production data set and add to the existing LCA model. Likewise, the economic modeling will be updated with the complete organic swine production data. Objective 5: We organized an Organic Swine and Hybrid Rye Field Day at the research site (WCROC, Morris, MN) on May 30, 2024, to showcase the project. The field day consisted of seminars and visiting organic swine facilities and the organic hybrid rye field. About 40 participants, including members of the project stakeholder advisory committee, organic livestock farmers, organic crop farmers, agricultural professionals, extension specialists, and researchers attended the field day. The seminar of the field day was livestreamed with about 500 plays. The research team and graduate students reported results of the project, and demonstrated how the project can help organic farmers improve production efficiency and profitability. A short video that was created by the research team that demonstrates tips for successfully raising organic pigs was shared with the audience. In addition to the field day, we showcased the project at the 2024 FarmFest Minnesota which was held from August 6th to 8th in Redwood Falls, MN. About 700 farmers, Ag professionals, extension specialists, and legislators across the state visited our booth over the three days. Additionally, we offered seminars and presentations at different conferences, meetings, and farmer events. We were invited to present a seminar (titled: Growing Hybrid Rye for Organic Pork Success) at the 2024 Minnesota Organic Conference to share results of the project and to discuss potential applications of the project outcomes to organic farms in the Midwest. About 30 people, including farmers and ag professionals, were in the audience. Furthermore, our graduate students presented two posters (1. Impact of Hybrid Rye on Pork Quality from Pigs Raised Organically; 2. Financial Viability of Growing Hybrid Rye to Feed and Bed Organic Pigs) at the 2024 Marbleseed Conference, the largest organic farming conference in the Midwest. One of the posters won third place in the graduate student competition at the Marbleseed Conference. We continued to deliver outcomes of the project to stakeholders, researchers, ag professionals and industry collaborators (e.g. Hormel Foods). For instance, results of the small-

plot trial over two years were shared at a local organic field day (the Steele County (MN) Organic Crops Day) on March 19, 2024 with 25 participants, including organic farmers, extension specialists, and ag professionals. Five oral and poster presentations were given at the UMN\'s extension and outreach events organized by the Forever Green Initiative group (a sustainable agricultural program sponsored by MN state legislature), the college (CFANS), and the department of Animal Science at UMN (see the list of products). Four factsheets/handouts were created and disseminated to farmers, stakeholders and agricultural professionals at these events. One short video on managing organic pigs was published on social media (YouTube). Additionally, two extension articles were published in The Land Magazine. Two abstracts were published at the Midwestern and National Annual Meetings of American Society of Animal Science (ASAS) in 2024 to disseminate outcomes of the project to broader audiences. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Kavanagh, M., G. Lima, A. Hilbrands, R. Cox, L. Johnston, and Y. Li. 2024. Effects of dietary hybrid rye on quality and consumer acceptability of pork from pigs raised under organic conditions. J. Anim. Sci. Vol. 102 (Suppl. 2) p. 58-59 (abstract). Available at: https://doi.org/10.1093/jas/skae102.068. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Li, Y., M. Kavanagh, G. Lim, A. Hilbrands, W. Lazarus, D. DeWitte, and L. Johnston. 2024. Integrating hybrid rye into organic pig production to reduce feed and bedding costs. 2024 ASAS-CSAS-WSASAS Annual Meeting, PSVII-29 (abstract). July 21-25, 2024. Calgary, AB. Canada. Available at: https://2024asasannual.eventscribe.net/posterAgenda.asp?startdate=7/23/2024&enddate=7/23/2024&pfp=PosterAgenda&mode= Type: Other Status: Published Year Published: 2024 Citation: DeWitte, D. 2024. Organic pigs and rye: The rest of the story. The Land Magazine. P. 9-11. Available at: https://landmagazine-cnhi.newsmemory.com/ Type: Other Status: Published Year Published: 2024 Citation: DeWitte, D. 2024. U of Ms research has always been about the alternatives. The Land. May 9, 2024. Available at: https://www.thelandonline.com/news/u-of-m-s-research-has-always-been-about-the-alternatives/article_d1af4bbe-0e4d-11ef-a18e-13aa8409607b.html Progress 09/01/22 to 08/31/23 Outputs Target Audience:The target audience for this project is organic farmers and their stakeholders, including organic certifiers, organic product marketers, as well as researchers, agriculturalprofessionals, and extension specialists. Outcomes of the propject havebeen disseminated to the audience through a field dayat the WCROC, presentationat the MN Organic Conference, and publicaitons in newsletters and on the university extenstion website and other social media. Changes/Problems: A team member, Mr. Curt Reese (Farm Manager), left the university in May 2023. Mr. Reese was responsible for organic winter hybrid rye production during the first two years of the project. By the time of Mr. Reese\'s departure, there were only three months before the organic hybrid rye being harvested. As a result, Mr. Reese\'s role was filled by other team members (Drs. Wilson, Tallaksen, and Garcia y Garcia), and the departure of Mr. Reese did not affect us achieving the goals of the project. Due to the significant increase in organic soybean meal (SBM) and organic corn price over the last two years, we are in a deep budget deficit. For instance, we budgeted \$9.5/bushel for organic corn and \$950/ton for organic SBM in the proposal. However, in 2022 when we conducted the pig feeding trial, the price for organic corn and SBM was \$11.5/bushel (21% increase) and \$1,690/ton (78% increase), respectively. For the entire feeding trial with 5 replicates, we will need 5,720 bushels of organic corn, and 69.2 tons of organic SBM. The price increase resulted in \$62,648 deficit in our budget (including \$11,440 deficit for organic corn, and \$51,208 deficit for organic SBM). To alleviate the budget deficit pressure, we propose to reduce the replicates of the pig feeding trial from five to four. We have conducted a power test based on our preliminary results of variation in final body weight of pigs from the project. By assuming to detect 5% reduction in final market weight (mean1 = 274 lb vs. mean2= 288 lb; SD = 30), the power test indicates that reducing replicates from five (250 pigs/treatment) to four (200 pigs/treatment) will not compromise the test power (\>0.85). So, we would like to request an approval from the USDA OREI program leaders to allow us to drop one replicate of the feeding trial. What opportunities for training and professional development has the project provided?The project provided educational opportunities for graduate students. Two graduate students (MS) have participated in the project and conducted the pig feeding trial since 2022 fall semester. The data generated from this project will contribute to their M.S. theses. The project also provided professional development for the team to attend organic conferences and interact with organic farmers and their stakeholders. How have the results been disseminated to communities of interest?Preliminary results have been disseminated to organic farmers, organic certifiers, ag. professionals, extension educators, researchers, and legislatures through presentations, demonstrations, and discussion at the MN organic conference, WCROC organic field day, the Forever Green Initiative Research and Discussion Meeting, North American Manure Expo, and University of Minnesota Extension events, as well as through publications in newspapers, newsletters, the university extension website, and other social media. Post event-evaluation was conducted which demonstrated that the outreach events were well received by organic farmers and their stakeholders. Participants indicated that they would share the information with others and were excited about the progress of the project. What do you plan to do during the next reporting period to accomplish the goals?Objective 1: We will complete soil sampling for the second (final) year of the small-plot field experiment. We will also get all soil and rye grain samples analyzed for P, N, K, pH, and organic matter to evaluate nutrient

cycling in the soil-plant systems as well as the impact of manure application on hybrid rye yield. We will conduct statistical analysis of the data and plan to publish a paper in a peer-reviewed journal. Additionally, we plan to present results at one or two farmer meetings. Objective 2: We will complete the pig feeding trial by conducting two additional replicates. We will farrow 32 sows to produce 200 organic pigs for the study. We will collect data on growth performance of pigs, N and P in pig manure, and nutrients in feed, carcass traits, and pork quality from pigs fed treatment diets (replacing 50% corn in control diets) vs. pigs fed control diets (corn soybean meal-based diets). We will conduct statistical analysis of the data from all replicates and present results at a regional organic conference (Annual Marbleseeds Conference, formerly known as MOSES), the Midwest Animal Science Annual meeting, and one or two farmer meetings. We plan to submit two manuscripts to peer-journals for publication. Objective 3 and 4: Data collected from the final year of swine work will be added to the existing LCA model.Cropping/soil simulations will be conducted for the rotations under development.Both the organic swine and crop/soil models will be compared with existing literature on swine and crop production. The economic modeling will be revised with the final year\'s crop and swine data. The soil, carbon, and economic models will be merged to develop recommendations for organic swine producers to enhance environmental and economic benefits of organic swine productions. We plan to generate two manuscripts for publication in peer-reviewed journals. Objective 5: We plan to organize a workshop/seminar at the MN Organic Conference and present a poster at the Marbleseeds Annual Conference. Additionally, we plan to submit three to four abstracts to the Midwest Animal Science Annual Meeting, Agronomy, Crop, and Soil Science Annual Meeting, and North Central Weed Science Society Annual Meeting. Additionally, we will generate one to two fact sheets, two short videos, and two extension articles. Impacts What was accomplished under these goals? Objective 1: We completed the second year of the small-plot field experiment evaluating manure management strategies for organic hybrid rye production. The second-year plot trial mirrored the first-year trial, in term of manure source (raw solid, composted solid, and liquid), manure application rate (0 as control, 60, 120, 180, and 240 lb/acres), replicates (n = 4), and data collection (soil N, P, K, pH, and organic matter). Stand count was conducted in November 2022 and May 2023. Rye grain was harvested in July 2023 and sampled for analysis of moisture content, test weight, and grain quality. In parallel to the small-plot study, organic hybrid rye was grown on 17 acres of an adjacent, organically certified land for the feeding trial to achieve Objective 2. Objective 2: We completed two replicates of the pig feeding trial. Within each replicate, 100 pigs that were born to 16 sows in a deep bedded farrowing barn were selected for the trial. Pigs were managed organically from prenatal (third trimester) to market weight (270 lb) according to the organic standards set by the National Organic Program (NOP). From 10 weeks old until market weight, pigs were fed control (organic corn soybean meal-based) or treatment (replacing 50% corn in the control diet with organic hybrid rye) diets. Control pens were bedded with organic wheat straw and treatment pens were bedded with organic hybrid rye straw. Organic hybrid rye grain and straw produced in 2022 was used for the first two replicates of the feeding trial. In both replicates, growth performance (average daily gain, average daily feed intake, and gain to feed ratio) of pigs was monitored. The bedding, manure pad, and fecal samples were collected for analysis of N and P concentration. At the end of the feeding trial, carcass traits (backfat thickness, loin area, and dressing percentage) and pork quality indicators (pH, shear force, water holding capacity, and color) were measured. Consumer acceptance of the pork was evaluated by a taste panel. Objective 3: During the past year, the project team has been collecting cropping and livestock data for rye and rye-based swine diets for use in LCA modeling. In addition, new swine and rye production scenarios are being developed to add to the three crop rotations initially identified and the baseline organic swine diet. The added rotations include a broader array of cover crops and focus on enhanced environmental benefits. Specific cover crops that have been identified include forage radish, camelina, and oats. These are to be tested as both standalone cover crops and as interseeded crops. Objective 4: For the soil modeling work, we have decided that the COMET farm model is the best option to examine the complex rotations and cover-crops being used in the organic crop production system. Compared to other models, COMET model allows the use of multiple crops in a single season and has a good number of choices in its cropping library. The model examines both soil carbon changes and nitrogen emissions, two important sources of carbon emissions/capture. A baseline corn-soybean rotation has been entered into the COMET model as part of the testing phase. An initial assessment of the rye-alfalfa- corn rotation has been conducted and indicates around 1.8 tons of carbon are captured per year with this rotation. Additionally, preliminary economic analysis was conducted using the data collected in 2022. The economic viability of growing winter hybrid rye for organic pigs as feed and bedding was discussed with organic farmers and their stakeholders at the field day on June 22, 2023 (see Objective 5 below). Objective 5: During the last reporting period, we organized a field day at the research site (WCROC, Morris, MN) on June 22, 2023 to showcase the project. The field day consisted of seminars, organic swine facility tours, and organic hybrid rye field walk. About 50 participants, including members of the project stakeholder advisory committee, organic livestock farmers, organic crop farmers, agricultural professionals, extension specialists, and researchers attended the field day. We shared outcomes of the project and demonstrated management strategies for growing winter hybrid rye organically, feeding hybrid rye to organic pigs, monitoring organic pigs using precision livestock farming technology (LeeO system), and enhancing economic viability of growing winter hybrid rye for organic pigs as feed and bedding. In

addition to the field day, we demonstrated the LeeO system at the 2023 FarmFest Minnesota which was held between August 1st and 3rd in Redwood Falls, MN. About 600 farmers, Ag professionals, extension specialists, and legislatures across the state visited our booth over the three days. Additionally, we offered seminars and presentations at different conferences, meetings, and farmer events. For instance, we organized a seminar (titled: A Pair with Potential: Hybrid Rye + Swine) at the 2023 Minnesota Organic Conference to share our findings from the project and discussed potential applications of the project outcome to organic farms in the Midwest. We also gave a seminar/webinar to stakeholders, researchers, and legislatures at the Forever Green Initiative (a sustainable agricultural program sponsored by MN state legislature) Research Updates and Discussion Meetings. Outcomes of the plot trial were shared at 2023 North American Manure Expo on August 9th in Arlington, WI. Three seminars regarding growing organic hybrid rye for pigs were offered at the University of Minnesota Extension events (UMN Extension Small Grains Updates) between January and March of 2023 in three locations (Morris, LeCenter, and Slayton) in Minnesota to reach farmers across the state. Furthermore, two factsheets and one short video were published to disseminate outcomes of the project to broader audiences. Progress of the project has been updated through publications in newsletters, The Land magazine, and on the university extension website and other social media. Publications Type: Other Status: Published Year Published: 2023 Citation: Yuzhi Li. 2023. Organic Swine Research: 2023. Article on WCROC website. May 1st, 2023. https://wcroc.cfans.umn.edu/about-us/wcroc-news/organic-swine-research. Type: Other Status: Published Year Published: 2023 Citation: Diane DeWitte. 2023. Swine & U: UMN research on organic hybrid rye and organic pigs. Article on swineweb.com. May 15, 2023. https://swineweb.com/swine-u-umn-research-on-organic-hybrid-rye-and-organic-pigs-by-diane-dewitte-umn-extension-swine-educator/ Type: Other Status: Published Year Published: 2023 Citation: Melissa Wilson, Yuzhi Li, and Curt Reese. 2023 (Factsheet). Evaluating different types of swine manure for hybrid rye production. Article in Stevens County Times: Features from the Farm. March 15, 2023; (This article has been published in several places to reach out to different audiences, including Crop News Post: Manure Update. March 28, 2023; UMN Extension, March 2023. https://blog-crop-news.extension.umn.edu/2023/03/manure-research-update-evaluating.html) Type: Other Status: Published Year Published: 2023 Citation: Lee Johnston, Yuzhi Li, Gabriella Lima, and Megan Kavanagh. 2023 (Factsheet). WCROC Pig ID in the Cloud. Article in Stevens County Times. January 24, 2023. Type: Other Status: Published Year Published: 2023 Citation: Megan Kavanagh, Gabriella Lima, Yuzhi Li, Lee J. Johnston. 2023. The LeeO system Pig production data at your fingertips. Article in Stevens County Times: Features from the Farm. March 21, 2023. Type: Other Status: Published Year Published: 2023 Citation: Diane DeWitte. 2023. Organic Rye is finding a home with hogs. The Land. Swine & U. April 14, 2023. https://z.umn.edu/SwineUApril2023 **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:The target audience for this project is organic farmers, their stakeholders, researchers, and agricultural professionals. General information about the project has been disseminated to the audiencethrough publications in newslettersand on the university extension websiteand other social media. Changes/Problems: The research team decided to move the first year's workshop and field day to the next year when the plot field data are analyzed and summarized. Dr. Jared Goplen, an extension educator in crop production, has left the University of Minnesota. We have replaced Dr. Goplen with Dr. Axel Garcia y Garcia, an associate professor of sustainable cropping systems and extension specialist at the Southwest Research and Outreach Center, University of Minnesota. Dr. Garcia y Garcia will take all the responsibilities assigned to Goplen in the proposal. What opportunities for training and professional development has the project provided?The project provided educational opportunities for graduate students. Two graduate students who are supported by this project have been recruited. They will start their M.S. programs in 2022 fall semester. How have the results been disseminated to communities of interest? No results are available at this point. In June of 2022, a co-PD (Dr. Joel Tallaksen) attended a USDA workshop in Ft. Collins, CO that examined how the USDA could increase their collaborations/support in US based ag LCA efforts. Among other goals, they hope to increase the amount of data from projects like this rye/swine project being added to the USDA National Agriculture Libraries LCA data collection. Dr. Tallaksen's presentation to the group included a discussion of this project and information that can be added to the USDA-NAL database. What do you plan to do during the next reporting period to accomplish the goals? Objective 1: we will start and complete the second (final) year of the small-plot field experiment. We'll also grow a second field of bulk hybrid rye for the organic pig feeding trials. We plan to hold one field day regarding hybrid rye production and will present results at one to two grower meetings. Objective 2: We will complete two pig feeding trials (there will be 5 trials in total for the project). We will collect on-farm data (growth performance, mortality and morbidity of pigs, N and P in pig manure, nutrients, and anti-nutrient factors in feed),carcass and pork quality data (carcass weight and length, loin area, backfat thickness, pork pH, color, water holding capacity, and shear force value), and will evaluate consumers' preference of pork from pigs fed hybrid rye. The results will be presented at a workshop/field day and one to two farmer meetings. Objective 3 and 4: Data collection from the final work on the first cropping season will be added to the LCA model.The first year of the swine data will be added to the model as well.Initial soil modeling will be started with the soil carbon emissions and N2O emissions compared with IPCC equations. These models and data will be evaluated by the project team for their feedback and discussion on improvements to increase accuracy. Objective 5: A

workshop/field day will be organized. A seminar or a poster will be presented at the MOSES annual conference. Preliminary results will be presented at one to two farmer meetings. Additionally, two fact sheets (manure management for organic hybrid rye, and record keeping for organic pig production), two short videos (growing winter organic hybrid rye, and manure application for organic hybrid rye), and two extension articles will be produced. **Impacts** What was accomplished under these goals? Objective 1: We completed one year of the small-plot field experiment evaluating manure management strategies for organic hybrid rye production. Three sources of swine manure (raw solid, composted solid, and liquid), each at five application rates (0 as control, 60, 120, 180, and 240 lb N/acre) were tested in four replicates on organically certified land. Manure samples of each source were collected and analyzed for total N, P, K, organic N, C:N ratio. Manure was applied September 2021 and the field was planted shortly after. Soil samples were collected before manure application and throughout the growing season for analysis of nitrate/ammonium, phosphorus, potassium, pH, and organic matter. Stand count was conducted in November 2021 and May 2022. Rye grain was harvested in July 2022 and sampled for analysis of moisture content, test weight, and grain quality. In parallel to the small-plot study, organic hybrid rye was grown on 20 acres of an adjacent, organically certified land. Objective 2: The first group of organic pigs were born to 16 sows in July 2022. Pigs were weaned at 6 weeks of ageand have been managed according to the organic standards set by the National Organic Program (NOP). Currently, pigs are 7 weeks old and housed in a deep-bedded nursery barn. The first feeding trial will start in September 2022 when pigs are 11 weeks old. Organic hybrid rye grain and straw produced forObjective 1 will be used for the feeding trial. Objective 3: We examined crop rotations that might fit with winter rye production in the Upper Midwest region. Potential rotations are being modeled using LCA software to examine greenhouse gas and fossil fuel impacts as part of an organic farm operation. Three rotations (listed below) were developed based on some basic practices for organic systems: 1) containing at least one rotation of perennial crop; 2) maintaining continuous cover on the land whenever possible. Rotation 1: Corn silage and Rye establishment - Rye and Alfalfa establishment - Alfalfa (2 years) - Corn grain and fall cover - Soy + fall cover. Rotation 2: Corn Silage and Rye establishment - Rye and Soy (relay) + fall cover - Corn Grain. Rotation 3: Corn Silage + Alfalfa Establishment - Alfalfa (2 years) - Corn Silage + Rye establishment. Objective 4: The LCA efforts have focused on tracking the activities of organic hybrid rye production for Objective 1. More specific LCA work will begin as yield data and harvest/storage operations are finished. Additionally, we have begun to explore soil models that can predict N~2~O and soil carbon variations due to cropping system changes. A likely candidate model for examining the soil variables is the COMET model, which can model multi-crop rotations with complex soil models using a web-based user interface. Objective 5: Progress of the project has been communicated with the advisory committee. Additionally, general information about the project has been disseminated through publications in newsletters andon the university extension website and other social media. **Publications** - Type: Other Status: Published Year Published: 2021 Citation: Yuzhi Li. 2021. Organic pigs and hybrid rye. WCROC News. Dec. 2021. Available at: <https://wcroc.cfans.umn.edu/about-us/wcroc-news/organic-pigs-hybrid-rye>. - Type: Websites Status: Published Year Published: 2022 Citation: Organic pigs and hybrid rye. swineweb.com. Jan. 5th, 2022. Available at: <https://www.swineweb.com/organic-pigs-and-hybrid-rye>. - Type: Other Status: Published Year Published: 2022 Citation: Organic pigs and hybrid rye. Stevens County Times. Features from the Farm. Jan. 25, 2022. - Type: Websites Status: Published Year Published: 2021 Citation: Diane DeWitte. 2021. University of Minnesota Swine Extension Program News Release. UMN Swine Extension Facebook, Sept 20, 2021. - Type: Other Status: Published Year Published: 2021 Citation: University of Minnesota Team Wins USDA Grant. AnSci Connection, UMN Dept of Animal Science Newsletter, Sept. 2021. - Type: Other Status: Published Year Published: 2021 Citation: U of MN team wins USDA grant for organic swine. WCROC News, Nov. 8, 2021. Available at: <https://wcroc.cfans.umn.edu/news/usda-swine-grant>. Type: Other Status: Published Year Published: 2021 Citation: Organic swine research set to continue at WCROC. UMN Swine Extension, Nov. 15, 2021.

↑ Return to Index

Expanding the Cover Crop Breeding Network: New Species and Traits for Organic Growers

Accession No.	1026683
Project No.	NYC-149646
Agency	NIFA NY.C\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34899
Proposal No.	2021-02952
Start Date	01 SEP 2021
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Investigator(s)	Moore, V.; Hayes, RY, JE.; Zwinger, ST, .; Stupar, RO, .; Ryan, MA, R..; Mirsky, ST, BR.; Ehlke, NA, JO.; McGee, RE, J..; Reberg-Horton, CH, .; Riday, HE, .; Leon-Gonzalez, RA, G.

NON-TECHNICAL SUMMARY

Cover crops are essential to the long-term sustainability of organic cropping systems because they suppress weeds, improve soil and water quality, supply nitrogen, and provide resources for beneficial organisms such as pollinators. Unlike cash crops, cover crops have not been bred for the traits that organic farmers need, and farmers have limited variety options and regional performance information. Our established team of organic and cover crop experts will expand a successful breeding and research program to include new cover crop species and address more traits of interest to organic growers. We will work with organic farmers and seed companies to breed new varieties of hairy vetch (Vicia villosa), winter pea (Pisum sativum), crimson clover (Trifolium incarnatum), and cereal rye (Secale cereale). Using classical breeding, marker-based selection, and participatory breeding, we will select varieties for agronomic traits of interest including weed suppression, early vigor, biomass production, winter hardiness, seed yield, disease and insect resistance, soft and non-shattering seed, and early flowering. Through release of new varieties and enhanced knowledge of regional cover crop adaptation, we will improve the ability of organic farmers to choose the cover crops best adapted to their region and cropping system. Our work directly addresses legislatively-defined OREI goals 1, 6, and 8 by facilitating development of organic production methods, conducting on-farm research, and developing new/improved seed varieties for organic systems. This project is unique because our network of research and farm sites ensures that our work is applicable across multiple regions, scales, and organic cropping systems.

OBJECTIVES

The major goals of this project are to breed cover crops for improved weed control and fertility management, and to facilitate farmer adoption of regionally appropriate cover crop varieties. The project objectives are to: Breed and release winter legume cover crops for traits of interest to organic growers. Improve winter survival using breeding nurseries, on-farm participatory plant breeding, high-throughput phenotyping, and optimal planting date studies. Select for early vigor, high biomass, disease resistance, and early maturity. Screen advanced breeding lines across the US to define regional and national winners for public variety release. Adapt a successful coordinated, multi-site model to establish a national cereal rye cover crop breeding program. Screen diverse germplasm for allelopathic ability. Select cereal rye for traits of interest to organic growers, including early vigor/establishment, early maturity, biomass production, and weed suppression. Screen advanced breeding lines

across the US to define regional and national winners for public variety release. Address barriers to the organic production of cover crop seed. Conduct a seed yield pathway analysis for crimson clover to improve seed yield. Identify seed weevil resistance in the hairy vetch germplasm. Use marker-assisted selection to develop hairy vetch cultivars with soft seed and reduced pod shatter. Compile data on cover crop variety performance and support farmer Extension and educational tools. Aggregate cover crop variety trial data from historical and future trials and farmer knowledge and experience. Exchange knowledge about variety performance with farmers, seed companies, and extension personnel through organic field days and participatory research. Structure variety performance data for integration with cover crop decision tools already available to organic farmers and extension personnel.

APPROACH

Vetch breeding nurseries. Six locations will host vetch breeding nurseries. For each plant, fall vigor, spring vigor, maturity, determinacy, disease, seed weight, and biomass at seed harvest will be recorded. Marker screening will be used to select for soft seed and low pod shatter. The best 2% of plants will advance to the next generation. Pea breeding nurseries. Nine locations will host pea breeding nurseries. Promising lines for traits of interest will be crossed in greenhouses and bulked into biparental families until the F3 generation. We will use the same methods described for vetch to measure fall vigor, spring vigor, maturity, disease, seed weight, and biomass at seed harvest. Through participatory plant breeding, organic farmers will host nurseries, pick biparental families of greatest interest for their operations, and select the best lines for harvest. Cold stress evaluation in growth chambers will be used to accelerate varietal improvement for winter hardiness, allowing up to three cycles of screening and selection per year. Peas will also be evaluated in disease nurseries for resistance to Aschochyta blight, white mold, and powdery mildew to inform selection and identification of resistant parents for new crosses. Rye breeding nurseries & allelopathy screening. In Year 1 of the project, we will conduct a preliminary in vitro screening of rye accessions from our breeding program, commercially available varieties, and the National Plant Germplasm System (NPGS). Rye material with the greatest allelopathic potential will be crossed to northern-adapted varieties to form the base breeding populations for the two northern nurseries. We will conduct rye selection nurseries at four locations representing hardiness zone 4-7. Phenotyping will be conducted as described previously for vetch, and each site will select the top 5% of individuals for advancement each year based on fall and spring vigor, winter survival, and maturity timing. In addition, NC and MD will conduct a field bioassay for allelopathy, in which the four breeding locations send seed of their top lines to be assessed for weed suppressive ability in a field with uniform weed pressure. Additional traits such as winter survival, biomass, heading date, and leaf rust resistance will be recorded on entries. These data will be used to select the best families from each breeding nursery. Advanced Line Trials. Seed from top selections in breeding nurseries will be increased each year. Lines with adequate seed after increase will be distributed to 14 advanced line trial sites. At each location, data will be collected on emergence, fall vigor, spring vigor, percent stand count at green up, and winter damage. Locations will collect biomass at one to two harvest dates that represent typical cover crop incorporation dates in theirregion andrecord maturity score, disease resistance, and vigor scores at harvest.All advanced breeding lines will be evaluated for seed yield in typical seed production regions. Data collected on each plot will include emergence, spring stand count, maturity rating, seed weight, biomass at seed harvest, viable seed, hard seed, and thousand seed weight. In Years 3-4, SeedLinked will coordinate on-farm testing on winter pea and cereal rye winter survival and overall performance using a triadic comparison model. We will conduct a trial with 40 growers per crop in USDA hardiness zones 3-5. An additional trial will define seeding dates that optimize winter survival in pea.Crimson clover seed yield. Seed yield will be studied from populations representing variability in seed yield from the past breeding program of crimson clover. The date of first flower will be recorded for each plant. At peak flowering, the number of stems per plant and inflorescences per stem will be recorded. Data on seed traitswill be used in path coefficient analysis to determine the direct and indirect influence of these variables on seed yield. DNA will be analyzed at WI to identify SSR markers, determine selfing rates among individuals, and include in correlations with seed yield. Bruchid beetle resistance. We will screen diverse lines of hairy vetch for resistance to bruchid beetle. We will plant 85 maternal lines that had the lowest numbers and 15 lines with the highest numbers of adult bruchid emergence. Bruchid populations will be monitored weekly around the trial. Once the first plant flowers in the nursery, researchers will visit every three days to determine date to first flower and date to first green pod of each plant in the trial. Six half-sibling progenies from each maternal line will be harvested, dried, and threshed, and seeds will be rated for bruchid presence. Remnant seed from plants with the lowest bruchid presence ratings will be entered into our nationwide vetch breeding nurseries to generate advanced breeding lines with bruchid resistance. Variety trial data aggregation. We will aggregate cover crop variety trial data following standard meta-analysis methods. Scientific literature databases, such as Web of Science, will be searched using keywords \"cover crop\" or \"catch crop\" or \"green manure\" combined with \"variety.\" General web searches using the same keywords will seek grey literature, such as extension publications and presentations. Growers and researchers with known cover crop experience will be personally

contacted and messages will be sent to grower listservs such as OGRAIN and researcher networks such as the cover crop councils (CCCs) to request information about historical and ongoing trials. Minimum criteria for data inclusion will include: 1) multiple varieties of at least one cover crop species tested and 2) location and year of the trial to associate with weather data and soil type. Evaluation of project impacts. Project impacts will be evaluated in terms of (1) the breadth and efficacy of stakeholder outreach, (2) the development of improved cover crop varieties that meet the needs of organic farmers, and (3) the generation of scientific knowledge to enhance future cover crop breeding efforts. Impacts of outreach activities will be measured in terms of both number of stakeholders reached and self-identified changes in knowledge or behavior. For example, we will track the number of attendees present at field days, presentations, and workshops associated with the project. We will conduct annual surveys of focus group participants regarding their use of named cover crop varieties. We will also track the number of page views for digital media and the number of citations for relevant publications. To evaluate the degree to which our cover crop varieties meet stakeholder needs, we will conduct participatory variety evaluation at regional field days. While viewing advanced line trial plots, farmers, seed company representatives, and extensionists will complete a standardized survey to identify their top two preferred varieties, least preferred variety, and provide any comments. In addition, we will work with SeedLinked to conduct on-farm variety trials to determine winter survival ability and evaluate overall performance of our breeding material. After the release of new cover crop varieties, we will work with companies to track regional seed sales as a proxy for cultivar adoption. To evaluate scientific knowledge and overall progress towards our project objectives, we will conduct annual in-person team meetings. They will take place in March of each year and will rotate between collaborating sites (NC in 2022, NY in 2023, OR or MN in 2024). These meetings will include presentations of preliminary results, a review of research progress, and facilitated discussions on research challenges and critical project needs. The advisory panel will be invited to annual meetings to provide feedback. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Our efforts reached a wide range of target audiences, including farmers, seed producers, seed companies, extension professionals, conservation/agricultural industry professionals, policymakers, other cover crop and plant breeding researchers, and undergraduate and graduate students. The project reached these audiences across multiple regions including the West, Northern Plains, Midwest, Mid-Atlantic, and Southeast. Changes/Problems:During FY2024, leadership of all CCB Network breeding programs changed. Collaborator Kissing Kucek secured a position as USDA-ARS Research Geneticist specializing in annual grass cover crop breeding, and as such, she assumed direction of the CCB Network cereal rye breeding program. In turn, USDA-ARS Research Geneticist Neal Tilhou assumed leadership of the CCB Network hairy vetch breeding program, with oversight from Co-PD Riday. With the retirement of Co-PD McGee, CCB Network coordinator Solveig Hanson assumed direction of the CCB Network winter pea breeding program. Finally, direction of the CCB Network crimson clover program transitioned to Marnin Wolfe of Auburn University. Co-PD Leon hired Postdoctoral Fellow Satransky to characterize root vs. shoot cereal rye allelopathy and quantify rye-to-rye allelopathy for high and low allelopathic lines. Co-PD McGee retired during FY2024, but her staff completed fall increases of CCB Network winter pea material. Unfortunately, a miscommunication resulted in the failure to plant a spring increase of CCB material. Researcher Mulkey (MN) again contributed F3 winter pea crosses to supplement previous CCB selections in 2024-25 nurseries. In addition, Dr. Kevin McPhee (Montana State University) has agreed to assist with winter pea increases in 2025, to replace the seed increase capacity that Co-PD McGee has provided. A Materials Transfer Agreement is in progress, led by Co-PD Riday, to grant CCB Network collaborators permission to breed with, trial, and increase material derived from Co-PD McGee\'s crosses. Winter pea variety and germplasm releases have been delayed due to Co-PD McGee\'s retirement, but these processes will resume after completion of the aforementioned MTA. Some locations experienced pest pressure, weed pressure, or weather conditions that limited their ability to collect data. In ND, a winter with unusually low (or absent) snow cover resulted in complete winterkill of winter pea nurseries and trials at both research station and on-farm sites. This winterkill considerably reduced both FTE allotted to the ND sites and outreach opportunities at those sites. The IA on-farm winter pea nursery was challenged by cool weather, slow pea maturity, and aggressive weed growth, rendering selection impossible. On-farm winter pea nurseries have been winnowed to two for the FY2025 season; we\'ve selected sites with reliable winter survival pressure and precedent of successful selection. Deer pressure and volunteer clover, respectively, rendered impossible the harvest of the University of Georgia pilot crimson clover nursery and NC crimson clover advanced line trial. Finally, pea weevil damage decreased seed yields in the large-plot winter pea increases undertaken by the WA PMC. These complications notwithstanding, the vast majority of CCB Network nurseries and trials were established successfully and yielded valuable data and germplasm. On-farm participatory variety trials used commercial winter pea varieties instead of CCB Network varieties, due to delays with germplasm release to the National Plant Germplasm System. Under the MTA currently being guided by Co-PD Riday, the CCB Network will have freedom to trial germplasm with on-farm collaborators and thus to integrate CCB Network advanced lines into 2025-26 on-farm trials. With the aid of collaborator Jiang\'s expertise and thermal imaging instruments, we are currently phenotyping hairy vetch accessions for bruchid damage. We will complete phenotyping this year, and if bruchid-resistant vetch lines are identified, they will be targeted for field and/or greenhouse planting in

2025. Publications summarizing four years of advanced line testing in crimson clover and winter pea were planned for 2023 publication, but these were delayed due to personnel transitions. Data for both crops have been re-analyzed to include 2022-23 data, providing more robust results, and publications will be submitted in 2024-25. What opportunities for training and professional development has the project provided?As part of this project, several graduate students and postdoctoral researchers were hired and trained on a wide range of field, laboratory, greenhouse, data analysis, and management skills. This included: 1 Postdoctoral researcher and 1 Master\'s student in North Carolina focused on rye allelopathy evaluation in laboratory and field conditions 1 Postdoctoral researcher in Wisconsin focused on analysis of marker and genomic data in charity vetch and crimson clover 1 PhD student in New York focused on winter survival and adaptation to northern environments in winter pea and cereal rye 1 PhD student in Wisconsin focused on breeding rye and understanding vetch toxicity to livestock 1 Master\'s student in Oregon focused on crimson clover seed yield pathway analysis 1 graduate student in Missouri was trained on conducting and analyzing field-based trials 3 undergraduate students in Wisconsin were hired to screen papers for inclusion in the project\'s cover crop variety performance database 1 undergraduate student in North Carolina learned about breeding nurseries, including making selections, seed harvest, and cleaning methods 1 undergraduate student in New York conducted thermal imaging analysis to investigate the genetic basis of bruchid resistance in hairy vetch Technicians, research support specialists, and undergraduate students were hired and trained across many project locations, and were trained in a wide range of activities including protocol development, planting research plots using cone-seeder drills, nursery and variety trial management and data collection, seed processing, and forage analysis. Finally, Co-PD Reberg-Horton\'s team hosted a new collaborator from University of Georgia for mentorship in crimson clover and hairy vetch nursery establishment. How have the results been disseminated to communities of interest?Collaborators hosted and/or presented project results at at least six field days in Minnesota, New York, Oregon, and Wisconsin. These events were attended by farmers, seed producers, and employees from multiple seed companies selling cover crop seed. Collaborators shared variety performance information and engaged in one-on-one meetings with 4 seed companies interested in licensing cover crop varieties from the breeding network. To ensure communication with companies unable to attend in-person field days, CCB Network Advanced Line Trial results were disseminated via email to a list of 32 seed industry contacts. Finally, Co-PD Riday and collaborator Kissing Kucek are continuing the release process for hairy vetch variety \'CCB Nitrous\' with Mountain View Seeds. PD Moore and collaborators represented the Cover Crop Breeding Network at the following events which reach farmers, seed growers, researchers, extensionists, and seed company representatives: Culinary Breeding Network Variety Showcase - Moore and Hanson (Oct 2023) New York Soil Health Cover Crop Field Walk - Moore and Hanson (Oct 2023) Oregon Clover Commission Meeting - Hayes (Oct 2023) New York Soil Health Alliance - Hanson (Nov 2023) Western New York Soil Health Alliance - Hanson (Dec 2023) University of Minnesota Winter Growers Meeting - Ehlke (2024) Oregon Seed Association Annual Meeting - Hayes (Jan 2024) Soil Health Collaborative - Kissing Kucek (Jan 2024) Northeast Cover Crop Council - Hanson (Feb 2024) Western Cover Crop Council - Hanson (March 2024) Oregon Seed Association - Hanson and Kissing Kucek (April 2024) Cover Crop Breeding Field Walks - Moore and Hanson (April-May 2024) Hyslop Farm Field Day - Hayes (May 2024) Spring Cover Crop Research Update - Riday and Kissing Kucek (June 2024) Cornell Seed Growers Field Day - Moore and Hanson (June 2024) PMCs have included information about Cover Crop Breeding Network efforts in their newsletters and annual reports to increase awareness among NRCS field staff and the public about the activities and benefits of this important work. What do you plan to do during the next reporting period to accomplish the goals?Objective 1: Breed and release winter legume cover crops for traits of interest to organic growers. Crimson clover, hairy vetch and winter pea breeding nurseries will be planted and evaluated across collaborating sites. After an initial screening nursery at the University of Georgia in 2023-24, that site will host two crimson clover nurseries with divergent breeding goals in 2024-25. In addition to four winter pea breeding nurseries on research stations, on-farm participatory pea breeding nurseries will be planted on two farms in the Upper Midwest. Seed increase will be conducted across species as in 2023-2024, with PMC\'s in KS, MO, and OR increasing 9 lines of hairy vetch and 12 lines of crimson clover. Advanced breeding line trials for legume species will continue at previous locations. The first year of on-farm participatory winter pea trials will continue, with a winter 2024-25 webinar on the CCB Network\'s winter pea breeding and research, along with instructional videos at each rating period. A second year of on-farm trials will be launched in August 2025 using the SeedLinked platform, this time using CCB Network advanced lines pending successful seed production. A publication summarizing five years of advanced line testing in hairy vetch was published in 2024, and similar publications for crimson clover and winter pea are in preparation with plans to publish in 2024-25. Objective 2: Adapt a successful coordinated, multi-site model to establish a national cereal rye cover crop breeding program. Collaborator Kissing Kucek arranged the first nationwide cereal rye variety trial for cover crop performance in the fall of 2024, sourcing 23 named varieties to be planted at ND, NC, OR, WI, and OK for fall vigor, winter survival, spring vigor, flowering time, biomass, forage quality, and/or seed yield. Cereal rye breeding nurseries with varied breeding goals with respect to planting date, flowering time, and allelopathy will be planted and evaluated in Minnesota (early flowering, high allelopathy), New York (early flowering, low allelopathy), and Wisconsin (planting after silage, late flowering, low

allelopathy; planting after grain corn, late flowering, high allelopathy). Concurrent field allelopathy screens in NC will inform selection for high and low allelopathy in MN and NY nurseries. Nurseries selecting for high allelopathy will be planted in MD and NC; in addition, NC will host a nursery breeding for strong agronomic performance in mid-south conditions. Finally, MN, NC, NY, and WI will increase populations harvested from 2023-24 cereal rye nurseries. Cereal rye advanced line trials comprising 22 entries will be added at 6 sites: MD, MO, NC, NY, OK, and WI. Entries include two bulks from 2023-24 CCB Network nurseries, experimental lines from Florida and Kentucky breeding programs, and 15 commercially available cultivars. Cereal rye advanced line trials use single-row plots, so to validate biomass yield against strip-scale plots, cereal rye biomass yield trials were planted in OR, ND, and WI using a subset of commercial cultivars. In New York, 2023-24 and two-year 2022-24 cereal rye variety x planting date data will be evaluated, and reports will be published. Objective 3: Address barriers to the organic production of cover crop seed. Co-PD Hayes will continue seed yield field experiments with crimson clover and hairy vetch. Hayes and graduate student Hale will finalize development of a pathway model for crimson clover seed yield. In addition, Hayes and graduate student Hale will analyze the diversity of seed yield components in 29 accessions originating from the USDA-NPGS. Evaluation of seed samples from the New York vetch bruchid nursery will be evaluated for bruchid infestation with leadership from collaborator Jiang. Lines with low infestation rates will be identified, and further evaluation in the field and/or greenhouse will be initiated. Collaborators Riday and Kissing Kucek will use the newly developed size-based marker to rapidly screen for soft seeded genotypes for inclusion in Fall 2024 hairy vetch breeding nurseries. This size-based marker was used in the 2023-2024 cycle and successfully increased the beneficial QTL frequency from 18% to 57% in the Wisconsin population. Also, a spring-planted Maryland nursery was screened for individuals with the QTL, resulting in a population with a beneficial (soft seed associated) QTL rate of 86%. Populations from these two entries are being tested in advanced line trials to validate QTL effects. Objective 4: Compile data on cover crop variety performance and support farmer Extension and educational tools. Collaborator Kissing Kucek\'s team will complete the Systematic Review with the National Agricultural Library to gather historical cover crop variety trial data. After filtering down to a few thousand papers that meet inclusion criteria, a database structure will be determined, and data from included papers will be inputted. The database will be hosted by National Ag Library and made publicly available. Impacts What was accomplished under these goals? Objective 1: Breed and release winter legume cover crops for traits of interest to organic growers Breeding Nurseries In Fall 2023, 5 crimson clover (CC), 5 hairy vetch (HV), and 5 winter pea (WP) nurseries were planted in locations across the US: GA, MD, MN, NC, ND, NY, and WI. Data were collected on emergence, vigor, winter survival, disease resistance, flowering time, and seed yield. Data were analyzed across traits of interest and selection recommendations were made for each breeding locations. For the outcrossing species (CC and HV), a balanced bulk of seed was created from each nursery site for entry into Fall 2024 advanced line trials and for seed increase. In addition, selected CC individuals were included in a half-sib trial to investigate seed yield of promising breeding lines. Seed Increase In Fall 2023 through Spring 2024, 8 populations of CC, 11 populations of HV, and 40 lines of WP were increased at NRCS Plant Materials Centers (PMCs) and ARS stations in KS, MO, OR, and WA. Advanced Breeding Line Trials In Fall 2023, advanced breeding line trials were planted in 14 locations across the US: AK, AL, GA, MD, MN, MO, NC, NY, OK, OR (2 locations), TX, WA, and WI. These locations include PMC, university, and ARS sites. The trials included crimson clover (28 entries), hairy vetch (40 entries), and winter pea (40 entries). Data collection included emergence, vigor, winter survival, disease resistance, flowering time, and biomass production. Winter Pea Variety x Planting Date Trial In Fall 2023, a third year of winter pea variety x planting date trials were planted in 3 locations in the northern US: MN, ND, and NY. The trial included 4 winter pea varieties and 4 planting dates between late August and mid-October. Data collection included emergence, vigor, winter survival, biomass production, and seed yield. Data were analyzed by graduate student Raksha Thapa (NY). The NY and MN trials yielded spring biomass data and grain yield data, respectively, but a harsh winter in ND resulted in complete winterkill. On-Farm Variety Trials On-farm participatory trials of commercially available winter pea varieties were planned for launch in Fall 2024. This included coordination with SeedLinked, recruitment of 70 trial participants in USDA hardiness zones 3-6, and development of a protocol. Variety Release Collaborator Kissing Kucek submitted internal USDA-ARS paperwork to release \'CCB Nitrous\' as a hairy vetch variety, which was approved internally through the PVP committee. Objective 2: Adapt a successful coordinated, multi-site model to establish a national cereal rye cover crop breeding program In Fall 2023, 7 cereal rye nurseries were planted in MD, MN, NY (3 nurseries), and NC (2 nurseries). Data were collected on emergence, vigor, winter survival, flowering time and seed yield. Data were analyzed and selections were made for separate early-maturing and late-maturing nurseries for Fall 2024 planting. Allelopathy nurseries in MD and NC collected data on lettuce presence and damage, which were compiled into an allelopathy index. Lines with highest allelopathy index advanced to 2024-2025 MD and NC allelopathy nurseries. Balanced bulks from selected 2023-24 cereal rye nurseries were entered into the first year of cereal rye advanced line trials, planted in Fall 2024. Selections from 2023-24 MN and NY early-flowering nurseries were sent concurrently to North Carolina for 2024-25 field allelopathy testing and to 2024-25 early-flowering nurseries; field allelopathy results will inform nursery selection Co-PD Leon and Postdoctoral Fellow Satransky continued laboratory and field experiments to

characterize cereal rye germplasm for allelopathic activity. Graduate student Warris characterized crop and weed susceptibility to rye lines varying in allelopathic activity under greenhouse conditions. Results show that heritability of rye allelopathy is high enough to justify breeding efforts for this trait. Furthermore, it was discovered that the sensitivity of crop or weed species to rye allelochemicals depends on the specific combination between target plant species and the allelopathic characteristics of each cereal rye genotype. A cereal rye variety trial was planted for a second year in Fall 2023. It included 14 varieties, including three NC advanced lines with improved allelopathy, and was planted on four planting dates at 6 locations in NY. Objective 3: Address barriers to the organic production of cover crop seed Co-PD Hayes conducted seed yield trials of 28 CC and 34 HV breeding lines and cultivars to identify those with high seed yield. Hayes conducted seed yield experiments with 72 half-sib families of crimson clover to identify early generation material with high seed yield. Data was collected on seed yield, total biomass, seed number, 1000 seed weight and harvest index. Percent defoliation from disease was collected on hairy vetch. Researcher Hanson completed analysis of previous half-sib crimson clover seed yield data. Hayes and graduate student Kimber Hale conducted pathway analysis of multi-site crimson clover space-planted nurseries to detect physiological drivers of seed yield in crimson clover. To investigate genetic components of bruchid beetle resistance in hairy vetch, an analytical pipeline was developed that combines imaging and thermal retention to detect intact versus bruchid-damaged seeds. Seed samples from the 2021-22 NY vetch bruchid nursery are being processed and then destructively examined for bruchid infestation, in order to validate this novel analytical method. Collaborators selecting for soft seed and reduced pod shatter collected hairy vetch seed, pods, and tissue samples for DNA analysis. Collaborator Kissing Kucek evaluated all selected hairy vetch from the 2023 cycle (n=800) for hard seed and pod shatter. Collaborator Kissing Kucek and Co-PD Riday evaluated 1200 soft seed and low shatter genotypes of vetch in Prairie du Sac, WI. Researcher Tilhou has identified a major QTL which reduces hard seed in hairy vetch. Prior breeding progress for hard seed has been slow and labor intensive. Collaborators Raasch, Riday, and Kissing Kucek developed a size-based marker to rapidly screen for soft seeded genotypes in the hairy vetch breeding program. Objective 4: Compile data on cover crop variety performance and support farmer Extension and educational tools PD Moore and collaborator Kissing Kucek continued efforts to develop a cover crop variety trial database. Collaborator Kissing Kucek collaborated with National Agricultural Library, USDA - Foreign Agricultural Service and Embrapa to conduct a systematic review of historical and current cover crop variety trial data. Over 18,000 papers were identified in the initial screen from the National Ag Library, and Collaborator Kissing Kucek hired three students to help screen the papers for inclusion in the database. Publications Type: Peer Reviewed Journal Articles Status: Published Year Published: 2023 Citation: Tilhou, N., L. Kissing Kucek, B. Carr, A. Marion, J. Douglas, J. Englert, S. Ali, J. Raasch, S. Bhamidimarri, S. Mirsky, M.J. Monteros, S. Krogman. 2023. Genome-wide association mapping in hairy vetch (Vicia villosa) discovers a large effect locus controlling seed dormancy. Frontiers in Plant Science. Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Tilhou, N., L. Kissing Kucek, B. Carr, J. Douglas, J. Englert, S. Ali, J. Raasch, S. Bhamidimarri, S. Mirsky, M.J. Monteros, H. Riday. 2024. Pooled DNA sequencing in hairy vetch (Vicia villosa Roth) reveals QTL for seed dormancy but not pod dehiscence. Frontiers in Plant Science. Type: Peer Reviewed Journal Articles Status: Published Year Published: 2023 Citation: Rebong D, Henriquez Inoa S, Moore VM, Reberg-Horton SC, Mirsky S, Murphy JP, Leon RG 2023. Breeding allelopathy in rye (Secale cereale) for weed suppression. Weed Science. Type: Other Journal Articles Status: Submitted Year Published: 2024 Citation: Thapa, R., S. Hanson, J. Hua, and V.M. Moore. Breeding for cold tolerance in common annual legume cover crops. Crop Science (Submitted) Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Kissing Kucek, L. et al. Cover Crop Breeding Strategies. ASA-CSA-SSSA, St. Louis, MO, October 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Moore, V. et al. Plant Breeding for Complex Systems. National Academies Panel Exploring Linkages Between Soil Health and Human Health. Sept 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Hanson, S. et al. Breeding for Biomass and Beyond: Cover crop breeding progress and potentials. Keystone Crops & Soil Conference. Harrisburg, PA, Nov 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Reberg-Horton, C. and Henriquez Inoa, E. Soil Health Resources: Cover Crop Selector Tools and a Farmer-Driven Coalition. Organic Commodities and Livestock Conference. Mount Olive, NC, March 2024. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Hanson, S. et al. Toward 40 million cover cropped acres: Breeding fall-sown cover crops for ecosystem services and farm system compatibility. Cornell Plant Breeding Symposium. April 2024. Progress 09/01/22 to 08/31/23 Outputs Target Audience:Our efforts reached a wide range of target audiences, including farmers, seed producers, seed companies, extension professionals, conservation/agricultural industry professionals, policymakers, other cover crop and plant breeding researchers, and undergraduate and graduate students. The project reached these audiences across multiple regions including the West, Northern Plains, Midwest, Mid-Atlantic, and Southeast. Changes/Problems:In January 2023, Dr. Solveig Hanson was hired to serve as program manager in a permanent Research Support Specialist position reporting to PD Moore. Researcher Hanson is responsible for network-wide nursery and trial coordination, analysis and selection for crimson clover and pea, and support of CCB Network

outreach, publications, and variety release. In August 2022, Co-PD Ryan passed all Cornell-based CCB Network activities to PD Moore. Co-PD Ryan continues to conduct cover cropping systems research synergistic to the efforts of the CCB Network. Postdoctoral researcher Rebong left his position with Co-PD Leon and has not yet been replaced. Co-PD McGee is beginning to phase out of CCB Network participation, as planned. While she was unable to contribute early-generation crosses for 2023-24 winter pea nurseries, researcher Mulkey (MN) contributed 24 F3 winter pea crosses in their stead. In addition, Dr. Kevin McPhee (Montana State University) has agreed to assist with winter pea increases in 2024, to replace the seed increase capacity that Co-PD McGee has provided. Some individual locations had pest pressure, weather conditions, or personnel challenges that limited their ability to plant or collect data. One of three participatory winter pea nurseries failed to establish due to late planting. For Fall 2023, researcher Mulkey (MN) custom-planted this nursery at an earlier date to ensure establishment. Fall 2022 advanced line trials planted in Fairbanks, Alaska failed to survive. To test viability of this location for future trials, Fall 2023 trials were sown in Fairbanks, AK and Palmer, AK using cultivars rather than CCB breeding material, and in both monoculture and biculture with triticale. After several years of unsuccessful crimson clover seed increases at Prosser, WA, we are happy to report that 2022-23 crimson clover at the Corvallis, OR PMC were successful. 2023-24 increases will use that site as well. Hairy vetch weediness (due to hard seed) and rodent damage is hampering the ability of the Aberdeen, ID PMC to properly increase hairy vetch seed, and therefore this site will be dropped for future seed increases. On-farm participatory variety trials were deferred from Fall 2023 to Fall 2024, to allow for USDA-ARS germplasm release of the CCB winter pea lines targeted for these trials. Trial planning with SeedLinked is underway. The timeline for research into hairy vetch bruchid beetle resistance was extended, as PD Moore and graduate student Everest concluded that a higher-throughput phenotyping method for bruchid screening was necessary. A collaboration with Dr. Yu Jiang, Cornell School of Integrated Plant Science-Horticulture was initiated and successful preliminary tests performed. With the aid of his lab\'s advanced seed imaging technology and expertise, we aim to identify bruchid-resistant vetch lines for field and/or greenhouse planting in 2024. Publications summarizing four years of advanced line testing in crimson clover and winter pea were planned for 2023 publication, but these were delayed due to personnel transitions. Data for both crops are being re-analyzed to include 2022-23 data, providing more robust results, and publications will be submitted in 2024. What opportunities for training and professional development has the project provided?As part of this project, several graduate students and postdoctoral researchers were hired and trained on a wide range of field, laboratory, greenhouse, data analysis, and management skills. This included: 1 PhD student in New York focused on winter survival and adaptation to northern environments in winter pea and cereal rye 1 Master\'s student in New York focused on vetch bruchid until December 2022 1 Postdoc and 1 graduate student in North Carolina focused on rye allelopathy evaluation in laboratory and field conditions 1 Master\'s student in Oregon focused on crimson clover seed yield pathway analysis 1 Postdoc in Wisconsin focused on analysis of marker and genomic data 1 undergraduate student in Wisconsin was mentored in a senior project which developed methods for measuring canavanine, a known toxic compound in vetch A research support specialist was hired to handle cover crop breeding network project management. Technicians, research support specialists, and undergraduate students were hired and trained across many project locations, and were trained in a wide range of activities including protocol development, planting research plots using cone-seeder drills, nursery and variety trial management and data collection, seed processing, and forage analysis. How have the results been disseminated to communities of interest?Collaborators hosted and/or presented project results at least seven field days in NY, Minnesota, and MD. These events were attended by farmers, seed producers, and employees from multiple seed companies selling cover crop seed. At some field days, we conducted participatory variety evaluation in which participants were asked to identify varieties of greatest interest to their farm or company and why. Collaborators also shared variety performance information and engaged in one-on-one meetings with 3 seed companies interested in licensing cover crop varieties from the breeding network. Collaborators Riday and Kissing Kucek established an MTA with Mountain View Seeds and are developing a license for new hairy vetch line \'CCB Nitrous.\' PD Moore also presented project results to farmers, researchers, extension, industry, and/or policymakers at the following events: Cover Crop Field Tour for NY State Congresspeople & Staffers (Oct 2022) Danforth Plant Science Center (Dec 2022) Cornell Seed Growers Conference (Dec 2022) New York Soil Health Summit (Dec 2022) Penn State Cover Crops Series (Feb 2023) Farm Bill Field Hearing with US Congresspeople & Staffers (April 2023) Cover Crop Breeding Field Walks (April-May 2023) Collaborators represented the Cover Crop Breeding Network at the following events which reach farmers, seed growers, and seed company representatives: Oregon Clover Commission Meeting - Hayes (Oct 2022) Oregon Seed Association Annual Meeting - Hayes (Jan 2023) State and National Soybean Boards Workshop - Mirsky (Jan 2023) National Predictive Modeling Tool Initiative - Mirsky (Feb 2023) Northeast Cover Crop Council - Mirsky (Feb 2023) Soil Health Collaborative - Kissing Kucek (Feb 2023) Southern Cover Crop Council - Reberg-Horton (Feb 2023) Organic Commodities and Livestock Conference - Reberg-Horton (March 2023) Grass Seed Field Tour - Ehlke (June 2023) PMCs have included information about Cover Crop Breeding Network efforts in their newsletters and annual reports to increase awareness among NRCS field staff and the public about the activities and benefits of this important work. What do you plan to do during the next reporting

period to accomplish the goals?Objective 1: Breed and release winter legume cover crops for traits of interest to organic growers. Crimson clover, hairy vetch and winter pea breeding nurseries will be planted and evaluated across collaborating sites. A new crimson clover breeding site will be added at the University of Georgia. In addition to research station breeding nurseries, on-farm participatory pea breeding nurseries will be planted on four farms in the Upper Midwest, including a new site in ND. Seed increase will be conducted across species as in 2022-2023, with PMCs in KS, MO, and OR increasing 10 lines of hairy vetch and 8 lines of crimson clover. Advanced breeding line trials will continue at previous locations, plus new locations in Oklahoma and Alabama. On-farm participatory variety trials conducted in coordination with SeedLinked will be planned and coordinated for planting in Fall 2024. A publication summarizing five years of advanced line testing in hairy vetch was submitted in 2023, and similar publications for crimson clover and winter pea are in preparation with plans to publish in 2024. A third year of the winter pea planting date x variety trial will be planted and evaluated in 4 locations: Minnesota, New York, North Dakota, and Washington. Objective 2: Adapt a successful coordinated, multi-site model to establish a national cereal rye cover crop breeding program. Cereal rye breeding nurseries will be planted and evaluated in Minnesota (1 nursery) and New York (2 nurseries). After selection for agronomic traits, half-sib family seed samples will be sent to NC for allelopathy screening, allowing selection for high or low allelopathy in 2024-25 nurseries. Field allelopathy screens will be carried out in NC and MD, and high allelopathy lines will be identified for advancement or use as parents. Seed will be increased for lines with favorable allelopathy and field performance traits, including the three advanced lines validated for allelopathy in 2022-23. In New York, 2022-23 cereal rye variety x planting date data will be evaluated, and a second year of the multi-site experiment will be planted at 6 NY sites in Fall 2023. The 2023-24 cereal rye variety x planting date experiment will test 14 varieties - including three high allelopathy lines from NC - over four planting dates. Objective 3: Address barriers to the organic production of cover crop seed. Co-PD Hayes (Oregon) will continue seed yield field experiments with crimson clover and hairy vetch. Hayes and graduate student Hale will develop a pathway model for crimson clover seed yield. Seed samples from the New York vetch bruchid nursery will be evaluated for bruchid infestation by collaborator Jiang. Lines with low infestation rates will be identified, and further evaluation in the field and/or greenhouse will be initiated. Collaborators Riday and Kissing Kucek will use the newly developed size-based marker to rapidly screen for soft seeded genotypes for inclusion in Fall 2024 hairy vetch breeding nurseries. Objective 4: Compile data on cover crop variety performance and support farmer Extension and educational tools. Collaborator Kissing Kucek is beginning a Systematic Review with the National Agricultural Library to gather historical cover crop variety trial data. Impacts What was accomplished under these goals? Objective 1: Breed and release winter legume cover crops for traits of interest to organic growers Breeding Nurseries In Fall 2022, 4 crimson clover nurseries were planted in Maryland (MD) and North Carolina (NC) (3 sites). Data were collected on emergence, vigor, winter survival, disease resistance, flowering time, and seed yield. Researcher Hanson analyzed field data across traits of interest and made selection recommendations for each breeding location. In Fall 2022, 7 hairy vetch nurseries comprising over 10,000 genotypes were planted in MD (2 sites), Minnesota, NY, NC (2 sites), and Wisconsin. Data were collected on emergence, vigor, winter survival, disease resistance, flowering time, and seed yield. Collaborator Kissing Kucek evaluated 800 vetch genotypes for hard seed and pod shatter, used a pedigree model to analyze over 90,000 hairy vetch genotypes for traits of interest, made selection recommendations for each breeding location, and assigned parents for Fall 2023 nursery planting. In Fall 2022, 5 winter pea nurseries were planted at research stations in MD, Minnesota, NY, NC, and North Dakota. Three on-farm winter pea nurseries were planted on collaborator organic farms in Wisconsin and Iowa. Data were collected on emergence, vigor, winter survival, disease resistance, flowering time, and seed yield. Researcher Hanson analyzed field data across traits of interest and made selection recommendations for each breeding location. Seed Increase In Fall 2022 through Spring 2023, 12 lines of crimson clover were successfully increased at the Corvallis, OR Plant Materials Center. Seed yield totaled almost 10 lbs among the 12 lines, averaging 264g per line and 4.72g per plant. All increased lines will be entered in advanced line trials in Fall 2023. During Fall 2023-Summer 2024, the Corvallis, OR PMC will increase 6 crimson clover breeding lines developed during the 2022 harvest season. In the fall of 2022, the Aberdeen, ID, Manhattan, KS, Elsberry, MO, and Corvallis, OR PMCs each established fields to increase a total of 11 promising lines of hairy vetch and twelve lines of crimson clover. Hairy vetch increases at Aberdeen, ID produced a total of 9.6 lbs. of 1 line (the other failed), at Manhattan, KS produced a total of 70 lbs. of 1 line (the other 2 failed), at Elsberry, MO a total of 272.3 lbs. among 2 lines, and at Corvallis, OR a total of 188 lbs. among 4 lines. The PMC increases will be used in further breeding efforts and for advance line testing at other locations. In Fall 2022 and Spring 2023, Co-PD McGee (USDA ARS - Pullman, WA) established fields to increase 40 lines of winter pea for use in breeding nurseries and advanced line trials. In Spring 2023, Co-PD McGee established larger plots to increase 6 winter pea lines in preparation for USDA-ARS germplasm release and on-farm variety trials. Advanced Breeding Line Trials In Fall 2022, advanced breeding line trials were planted in 13 locations across the US: Alaska, Georgia, MD, Minnesota, Missouri, NY, NC, ND, Oregon (OR) (2 locations), Texas, Washington, and Wisconsin. These locations include 4 PMC sites: Americus, GA, Corvallis, OR, Knox City, TX, and Pullman, WA. The trials included crimson clover (12 entries), hairy vetch (43 entries), and winter pea (38 entries). Data

collection included emergence, vigor, winter survival, disease resistance, flowering time, and biomass production. Winter Pea Variety x Planting Date Trial In Fall 2022, a second year of winter pea variety x planting date trials were planted in 3 locations in the northern US: Minnesota, NY, and ND. The trial included 4 winter pea varieties and 4 planting dates between late August and mid-October. Data collection included emergence, vigor, winter survival, biomass production, and seed yield. Data were analyzed by graduate student Raksha Thapa (NY). Variety Release Collaborator Kissing Kucek submitted paperwork to release \'CCB Nitrous\' as a PVP hairy vetch variety. Objective 2: Adapt a successful coordinated, multi-site model to establish a national cereal rye cover crop breeding program In Fall 2022, 2 cereal rye nurseries were planted, in New York and Minnesota. The NY nursery comprised both early (September 30) and late (October 26) planting dates, while the Minnesota nursery was planted on September 13, 2022. Both nurseries included selections from the NC allelopathy breeding program, in addition to PI accessions with reported adaptation to northern climates. Data were collected on emergence, vigor, winter survival, and seed yield. Data were analyzed by researcher Hanson, and selections were made for separate early-maturing and late-maturing nurseries for Fall 2023 planting. Collaborator Kissing Kucek devised a rye breeding pipeline schematic for future CCB use. Collaborator Leon and postdoctoral fellow Rebong continued laboratory and field experiments to characterize cereal rye germplasm for allelopathic activity. New crosses were made, and progenies of allelopathic x Northern-adapted crosses were evaluated for increased allelopathy in vitro and under greenhouse conditions. For three lines previously selected for high allelopathy, allelopathic properties were confirmed under field conditions, and seed was increased. Graduate student Warris characterized crop and weed susceptibility to rye lines varying in allelopathic activity under greenhouse conditions. A cereal rye variety trial was planted in Fall 2022, which included eight varieties and four planting dates at 6 locations in NYState. Objective 3: Address barriers to the organic production of cover crop seed Co-PD Hayes (Oregon) conducted seed yield trials of advanced breeding lines of crimson clover and hairy vetch to identify breeding lines with high seed yield. Hayes conducted seed yield experiments with half-sib families of crimson clover to identify early generation material with high seed yield. Hayes and graduate student Kimber Hale (Oregon) also conducted replicated, space planted nurseries containing six crimson clover populations in OR, TX, and NC to study seed yield components. Material was harvested and data was collected on seed yield components. Analysis is underway. Seed samples from the 2021-22 New York vetch bruchid nursery were processed, but it was determined that more advanced imaging techniques were needed to accurately and efficiently screen seed samples for bruchid infestation. A collaboration was initiated with Dr. Yu Jiang, Cornell School of Integrated Plant Sciences - Horticulture, who specializes in horticultural image analysis. Dr. Jiang found promising results from preliminary tests of a vetch seed imaging technique, and he is developing a formal protocol to standardize data acquisition and analysis. Collaborators selecting for soft seed and reduced pod shatter collected hairy vetch seed, pods, and tissue samples for DNA analysis. Collaborator Kissing Kucek evaluated 800 vetch genotypes for hard seed and pod shatter. Kissing Kucek and Co-PD Riday grew and phenotyped 1200 soft seed and low shatter genotypes of vetch in Prairie du Sac, WI. They selected the best 3% of plants to advance in subsequent nurseries. Postdoctoral researcher Tilhou identified major QTL for hard seed in hairy vetch. Collaborators Raasch, Riday, and Kissing Kucek developed a size-based marker to rapidly screen for soft seeded genotypes in the hairy vetch breeding program. Objective 4: Compile data on cover crop variety performance and support farmer Extension and educational tools PD Moore and Collaborator Kissing Kucek continued efforts to develop a cover crop variety trial database. Collaborator Kissing Kucek put out a call for historical and current cover crop variety trial data. She compiled data on historical rye, winter pea, and hairy vetch variety testing to identify best lines, and presented results at the Organic Vegetable Producers Conference in 2023. Publications Type: Journal Articles Status: Published Year Published: 2023 Citation: Ali, S., L. Kissing Kucek, H. Riday, N. Krom, S. Krogman, K. Cooper, L. Jacobs, P. Mehta, M. Trammell, S. Bhamidimarri, T. Butler, M.C. Saha, M.J. Monteros. 2023. Transcript Profiling of Hairy Vetch (Vicia villosa Roth) identified interesting genes for seed qualities. The Plant Genome, 16(2). Type: Journal Articles Status: Published Year Published: 2023 Citation: Moore, V., T. Peters, B. Schlautman, C. Brummer. 2023. Toward plant breeding for multicrop systems. Proceedings of the National Academy of Sciences, 120(14). Type: Journal Articles Status: Published Year Published: 2023 Citation: Poffenbarger, H., M. Castellano, D. Egli, A. Jaconi, V. Moore. 2023. Contributions of plant breeding to soil carbon storage: Retrospect and prospects. Crop Science, 63:990-1018. Type: Journal Articles Status: Submitted Year Published: 2023 Citation: Tilhou, N., L. Kissing Kucek, B. Carr, A. Marion, J. Douglas, J. Englert, S. Ali, J. Raasch, S. Bhamidimarri, S. Mirsky, M.J. Monteros, S. Krogman. 2023. Genome-wide association mapping in hairy vetch (Vicia villosa) discovers a large effect locus controlling seed dormancy. Frontiers in Plant Science. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Everest, E. L. Kissing Kucek, et al. Screening for Hairy Vetch (Vicia villosa) Genotypes with Resistance to Vetch Bruchid (Bruchus brachialis). ASA-CSSA-SSSA Meetings, Baltimore, MD, Nov 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Thapa, R., L. Kissing Kucek, et al. Evaluation of Planting Dates in Winter Pea (Pisum sativum L.) to Optimize Winter Survival and Biomass Production. ASA-CSSA-SSSA Meetings, Baltimore, MD, Nov 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Moore, V. et al. Plant Breeding for Diverse Cropping Systems. Danforth Plant

Science Center, Dec 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Moore, V. et al. Opportunities in Plant Breeding for Soil Health. New York Soil Health Alliance, Dec 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Moore, V. et al. Cover Crop Breeding for the Northern US. Cornell Seed Growers Conference, Dec 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Kissing Kucek, L. et al. Genetic and Environmental Drivers of Legume Cover Crop Performance. Plant and Animal Genome Conference, San Diego, CA, Jan 2023. Type: Journal Articles Status: Published Year Published: 2023 Citation: Fuller, T., L.M. Koch, L. Kissing Kucek, S. Ali, H. Mangelson, T. Hernandez, T. P.L. Smith, D.M. Bickhart, H. Riday, M.L. Sullivan. 2023. A reference assembly for the legume cover crop, hairy vetch (Vicia villosa Roth). Gigascience. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Moore, V. et al. Breeding Legumes for Diverse Cropping Systems. Plant and Animal Genome Conference, San Diego, CA, Jan 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Moore, V. et al. Advances in legume cover crop breeding. Penn State Cover Crop Series: Making cover crops pay. Feb 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Kissing Kucek, L. and K. Becker. Cover Crop Varieties and Why They Matter. Organic Vegetable Producers Conference, Madison, WI, Feb 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Reberg-Horton, C. and A. Woodley. Practical Guide to Working with Cover Crops from Species Selection to Residue Management. Organic Commodities & Livestock Conference, Raleigh, NC, March 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Kissing Kucek, L., Hanson, S., and N. Enjalbert. Participatory Plant Breeding. National Association of Plant Breeders, Greenville, SC, July 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Kissing Kucek, L. and L. Bastos Martins. Big Picture of Winter Peas. Albert Lea Seed Winter Grains and Cover Crop Conference, Virtual, July 2023. Type: Other Status: Accepted Year Published: 2023 Citation: CCB Nitrous Hairy Vetch Variety Release approved by USDA-ARS National Programs. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:Our efforts reached a wide range of target audiences, including farmers, seed producers, seed companies, extension professionals, conservation/agricultural industry professionals, policymakers, other cover crop and plant breeding researchers, and undergraduate and graduate students. The project reached these audiences across multiple regions including the West, Northern Plains, Midwest, Mid-Atlantic, and Southeast. Changes/Problems:The team has had difficulties hiring and retaining a program manager. The position was initially hired as a postdoc, and after multiple rounds of searching, a postdoc was hired starting in December 2021, but this individual departed the team for another position in June 2022. Thereafter we decided to recruit a program manager in a permanent staff role and identified a candidate to start in January 2023. Long periods without a dedicated program manager were challenging for the team and led to some delays in achieving project objectives (e.g., publications, variety release, and database development) as some key personnel took on additional management and analysis roles to keep the breeding network operating smoothly. However, we are optimistic that the new hire will remain with the project long-term and her addition to the team will free other collaborators to focus on the full set of project objectives. Some individual locations also had pest pressure, weather conditions, or personnel challenges that limited their ability to plant or collect data. Seed increase of crimson clover has continued to be a challenge. We have attempted to increase seed in Prosser, WA for two years with poor results, which has limited the number of entries that can be tested in our advanced breeding line trials. In 2022-2023 we will attempt to conduct increases in both Prosser and Corvallis to spread risk. COVID restrictions continued to impact the ability to hold field days and participatory evaluations at the PMCs and some other collaborating locations. We hosted our first in-person annual meeting since the COVID pandemic in Corvallis, OR. The meeting was largely successful, but some collaborators were unable to join because of uncertainty around travel policies that were not resolved until close to the date of the meeting. What opportunities for training and professional development has the project provided? As part of this project, several graduate students and postdoctoral researchers were hired and trained on a wide range of field, laboratory, greenhouse, data analysis, and management skills. This included: 1 Postdoc in New York focused on cover crop breeding network project management 1 PhD student in New York focused on winter survival and adpatation to northern environments in winter pea and cereal rye 1 Master's student in New York focused on vetch bruchid 1 Postdoc and 2 graduate students in North Carolina focused on allelopathy evaluation in laboratory and field conditions 1 PhD student in North Carolina graduated and started a job with a seed company focused on emerging crops including winter pea and other cover crop species 1 Master's student in Oregon focused on crimson clover seed yield pathway analysis 1 Postdoc in Wisconsin focused on analysis of marker and genomic data Technicians, research support specialists, and undergraduate students were hired and trained across many project locations, and were trained in a wide range of activities including protocol development, planting research plots using cone-seeder drills, nursery and variety trial management and data collection, seed processing, and forage analysis. How have the results been disseminated to communities of interest? Collaborators hosted and/or presented project results for at least 10 field days in Minnesota, New York, North Carolina, North Dakota, Oregon, and Wisconsin. These events were attended by farmers, seed producers, and employees from multiple

seed companies selling cover crop seed. At some field days, in addition to research presentations, we conducted participatory variety evaluation in which participants were asked to identify varieties of greatest interest to their farm or company and why. Collaborators also shared variety performance information and engaged in one-on-one meetings with 2 seed companies interested in licensing cover crop varieties from the breeding network. PD Moore also presented project results to farmers, researchers, extension, industry, and/or policymakers at the following events: ASA-CSSA-SSSA Annual Meeting (Nov. 2021) Northeast Agribusiness & CCA Conference (Dec. 2021) University of Kentucky Dept. of Plant & Soil Sciences departmental seminar (April 2022) Presentation to Rodale Institute Consulting team (June 2022) Tour & project overview with current US Senator & staff (Aug. 2022) What do you plan to do during the next reporting period to accomplish the goals? Objective 1: Breed and release winter legume cover crops for traits of interest to organic growers. Crimson clover, hairy vetch and winter pea breeding nurseries will be planted and evaluated across collaborating sites. In addition to research station breeding nurseries, on-farm participatory pea breeding nurseries will be planted on three farms in the Upper Midwest. Seed increase will be conducted across species as in 2021-2022. Advanced breeding line trials will continue at previous locations. A new site in Alaska has been recruited and will participate in 2022-2023 trials to test survival under extreme winter conditions. On-farm participatory variety trials conducted in coordination with SeedLinked will be planned and coordinated for planting in Fall 2023. Publications summarizing four years of advanced line testing in crimson clover, hairy vetch and winter pea are in preparation with plans to publish in 2023. A second year of the winter pea planting date x variety trial will be planted and evaluated in 3 locations: Minnesota, New York, and North Dakota. Objective 2: Adapt a successful coordinated, multi-site model to establish a national cereal rye cover crop breeding program. Cereal rye breeding nurseries will be planted and evaluated in Maryland, Minnesota, New York and North Carolina. The first round of field performance experiments for new highly allelopathic lines will be done in NC and MD. The top 10% lines will be selected at the end of the season. Field trials will be conducted to generate data about allelopathic potential and agronomic performance of three lines for cultivar release. This will be done in three NC locations. In New York, the cereal rye variety x planting date experiment will be evaluated and a second year of the experiment will be planted in Fall 2023. A multi-location advanced breeding line trial similar to that conducted for legume species will be planned and initiated in Fall 2023. Objective 3: Address barriers to the organic production of cover crop seed. Co-PD Hayes (Oregon) will continue seed yield field experiments with crimson clover and hairy vetch. Complete data collection and analysis of crimson clover seed yield components. Seed samples from the New York vetch bruchid nursery will be processed and evaluated for bruchid infestation. Lines with low infestation rates will be identified and further evaluation in the field and/or greenhouse will be initiated. Collaborator Kissing Kucek will coordinate the screening of 1000 vetch lines collected from nationwide 2022 nurseries for hard seed and pod shatter. Objective 4: Compile data on cover crop variety performance and support farmer Extension and educational tools. Collaborators will continue efforts to compile cover crop variety performance data and finalize protocols and structure for the database. **Impacts** What was accomplished under these goals? **Objective 1: Breed and release winter legume cover crops for traits of interest to organic growers**. **Breeding Nurseries**. In Fall 2021, 4 crimson clover nurseries were planted in Maryland and North Carolina (three sites). Data were collected on emergence, vigor, winter survival, disease resistance, flowering time, and seed yield. PD Moore analyzed field data across traits of interest and made selection recommendations for each breeding location. In Fall 2021, 8 hairy vetch nurseries were planted in Maryland (two sites), New York, North Carolina (two sites), Oregon (two sites), and Wisconsin. Data were collected on emergence, vigor, winter survival, disease resistance, flowering time, seed yield, hard seed, and pod shattering. Collaborator Kissing Kucek analyzed field data across traits of interest and made selection recommendations for each breeding location. In Fall 2021, 5 winter pea nurseries were planted in Maryland, Minnesota, New York, North Carolina, and North Dakota. Data were collected on emergence, vigor, winter survival, disease resistance, flowering time, and seed yield. PD Moore analyzed field data across traits of interest and made selection recommendations for each breeding location. **Seed Increase**. In Fall 2021, 10 lines of crimson clover were increased at the USDA NPGS location in Prosser, WA. Seed yields were relatively low for unknown reasons, and an additional seed increase location at the Corvallis, OR PMC was identified for 2022 crimson clover seed increases. The Corvallis PMC plans to increase 12 crimson clover lines in 2022-2023. In Fall 2021, the Aberdeen, ID, Manhattan, KS, Elsberry, MO, and Corvallis, OR PMCs each established fields to increase eleven promising lines of hairy vetch. Hairy vetch increases at Aberdeen, ID produced a total of 25.9 lbs. among 3 lines, at Manhattan, MS produced a total of 24.15 lbs. among 3 lines, at Elsberry, MO a total of 2.97 lbs. among 2 lines, and at Corvallis, OR a total of over 146 lbs. of 3 lines. In the 2022-2023 seed production season, PMCs in ID, KS, MO, and OR are again increasing 11 lines of hairy vetch. All lines are being planted in fall 2022. PMCs will return the seed to the breeders for further evaluation, another round of seed increase, and/or for field-testing as needed. In Fall 2021 and Spring 2022, co-PD McGee (USDA ARS - Pullman, WA) established fields to increase 70 lines of winter pea for use in breeding nurseries and variety trials. **Advanced Breeding Line Trials**. In Fall 2021, advanced breeding line trials were planted in 14 locations across the US: Georgia, Maryland, Minnesota, Missouri, Nebraska, New York, North Carolina (2 locations), North Dakota, Oregon (2 locations), Texas, Washington, and Wisconsin. The trials

included crimson clover (13 varieties), hairy vetch (21 varieties), and winter pea (28 varieties). Data collection included emergence, vigor, winter survival, disease resistance, flowering time, and biomass production. **Winter Pea Variety x Planting Date Trial**. In Fall 2021, winter pea variety x planting date trials were planted in 4 locations in the northern US: Minnesota, Montana, New York, and North Dakota. The trial included 4 winter pea varieties and 4 planting dates between late August and mid-October. Data collection included emergence, vigor, winter survival, biomass production, and seed yield. Data were analyzed by graduate student Raksha Thapa (New York). **Objective 2: Adapt a successful coordinated, multi-site model to establish a national cereal rye cover crop breeding program**. In Fall 2021, 3 cereal rye nurseries were planted in Maryland, New York, and North Carolina. The New York nursery failed to establish because of late planting due to abnormally wet fall conditions. Data from Maryland and North Carolina were collected on emergence, vigor, winter survival, allelopathic ability, and seed yield. Data were analyzed by personnel at each site. Experiments were conducted in laboratory to characterize cereal rye germplasm for allelopathic activity. Approximately 50 lines were identified as highly allelopathic were crossed under greenhouse conditions with 'Aroostook' and 'ND Gardner'. Resulting lines were screened under laboratory conditions to confirm allelopathic activity. Nurseries of new cross were grown under greenhouse conditions. Three lines that had been selected for allelopathic activity were grown in isolation for seed increase. In New York, a cereal rye variety trial was planted in Fall 2021 as an initial assessment of variety performance at a northern location. However, the trial had limited emergence because of late planting due to abnormally wet fall conditions. A new trial, including multiple planting dates at 6 locations in New York State, was planned for Fall 2022. A protocol was developed for rye nurseries to be planted in northern locations (Minnesota and New York) for evaluation and selection based on agronomic traits. The nurseries were planned for Fall 2022. **Objective 3: Address barriers to the organic production of cover crop seed.** Co-PD Hayes (Oregon) conducted seed yield trails of advanced breeding lines of crimson clover and hairy vetch and conducted seed yield trails of crimson clover half sib families. Co-PD Hayes and graduate student Kimber Hale (Oregon) also conducted a space planted nursery of crimson clover to study seed yield components. Material was harvested and data is being collected. Plans were made to repeat the study in three additional locations in Fall 2022. PD Moore and graduate student Erika Everest (New York) planted a hairy vetch nursery to evaluate and select for vetch bruchid resistance. The nursery included breeding lines, USDA NPGS accessions, and commercial varieties. Data collection included emergence, date of first flower and first pod set, and presence of vetch bruchids. Seed from each plant was harvested and will be evaluated for bruchid infestation in winter 2022-2023. Vetch bruchid oviposition and infestation were also evaluated in the New York advanced breeding line trial to determine whether breeding lines already showed differences in resistance. Collaborators selecting for soft seed and reduced pod shatter collected hairy vetch seed, pods, and tissue samples for DNA analysis. Collaborator Kissing Kucek (Wisconsin) screened 1002 samples from nationwide 2021 vetch nurseries for visual pod shatter, force to pod shatter, and hard seed. **Objective 4: Compile data on cover crop variety performance and support farmer Extension and educational tools**. PD Moore and Collaborator Kissing Kucek initiated efforts to develop a cover crop variety trial database. This included searching peer reviewed and extension literature for published variety trials and meeting with other researchers conducting variety trials to request input on the structure of the database and contributions of unpublished variety trial data. **Publications** - Type: Journal Articles Status: Submitted Year Published: 2022 Citation: Ali, S. et al. Transcript Profiling of Hairy Vetch (Vicia villosa Roth) identified interesting genes for seed qualities. The Plant Genome. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Bastos Martins, L., R.M. Rejesus, C. Reberg-Horton, and R.L Myers. 2021. Understanding the market for cover crop seeds in the United States: Background and potential policy directions. Journal of Soil & Water Conservation 76: 5. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Kissing Kucek, L. et al. Advances in Hairy Vetch Breeding for Cover Crop Use Joint Conference NAAIC, Trifolium, & Grass Breeders, June 8, 2022. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Moore, V. et al. Winter Annual Cover Crop Species and Variety Performance in Multi-Environment Trials. ASA-CSA-SSSA, November 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Muller, K., Kissing Kucek, L. et al. All About Legumes Part I: Cover Crops Practical Farmers of Iowa Annual Meeting. Ames, IA. January 22, 2022. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Muller, K., Kissing Kucek, L. et al. Breeding for Symbiotic Nitrogen Fixation in Legume Green Manure Crops: Lessons Learned and Future Challenges. ASA-CSA-SSSA, November 2021. - Type: Journal Articles Status: Under Review Year Published: 2022 Citation: Poffenbarger, H., M. Castellano, D. Egli, A. Jaconi, and V. Moore. Contributions of plant breeding to soil carbon storage: Retrospect and prospects. Crop Science. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Moore, V. Forage and cover crop breeding for New York State. Northeast Agribusiness & CCA Conference, Dec. 1. 2021.

↑ Return to Index

Mulch2o: Biodegradable Composite Hydromulches for Sustainable Organic Horticulture

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NON-TECHNICAL SUMMARY

Currently, organic horticultural producers are heavily reliant on non-biodegradable plastic mulches for weed suppression and soil moisture conservation, but disposal of these mulches is expensive and environmentally unsound. Biodegradable plastic mulches (BDMs) are available and allowed in organic production, but currently no commercially available BDMs meet the NOP\'s requirements for use because none consist only of 100% bio-based feedstocks and many feedstocks are sourced from GMOs. The long-term goal of the proposed research is to develop composite cellulose-based hydro-applied biodegradable mulches (i.e., hydromulches) that could replace non-biodegradable plastic mulches in organic horticultural systems.Economically and environmentally, organic horticulture producers and society at large will benefit from the development of cost-effective biodegradable alternatives to plastic mulches. Environmental (agroecological) benefits will be quantified by assessing weed suppressive abilities and soil health impacts associated with the composite hydro-applied mulches we develop. Cost-benefit analyses will document the economic impacts of using composite hydromulches instead of conventional plastic mulches.

OBJECTIVES

Major goal: Currently, organic horticultural producers are heavily reliant on non-biodegradable plastic mulches for weed suppression and soil moisture conservation, but disposal of these mulches is expensive and environmentally unsound. Biodegradable plastic mulches (BDMs) are available and allowed in organic production, but currently no commercially available BDMs meet the NOP\'s requirements for use because none consist only of 100% bio-based feedstocks and many feedstocks are sourced from GMOs. The long-term goal of the proposed research is to develop composite cellulose-based hydro-applied biodegradable mulches (i.e., hydromulches) that could replace non-biodegradable plastic mulches in organic horticultural systems. Overall Objective: Design, develop and evaluate the performance (weed suppression, crop quality and yield), ecological (soil health impacts), and economic impacts associated with using biodegradable composite hydromulches in organic horticultural production systems. Sub-Objective 1: Design and develop biodegradable composite hydromulch formulations; evaluate hydromulch formulation impact on weed suppressive ability in a controlled environment. Sub-Objective 2: Develop and test hydromulch application technologies. Sub-Objective 3: Evaluate hydromulch efficacy and impact on crop quality and yield in annual day-neutral strawberry production systems. Sub-Objective 4: Evaluate hydromulch efficacy and impact on crop quality and yield and soil health indicators (co-

PD Weyers, USDA-ARS Morris MN) in perennial blueberry production (co-PD DeVetter, Justin Ellgen, Jake Warvin, PhD student) and in annual market vegetable production. Sub-Objective 5: Assess the economic impacts of hydromulch applications in the organic production of blueberry, onion, and broccoli via cost-benefit analyses. Sub-Objective 6: Conduct outreach and extension activities to disseminate results to stakeholders, including organic farmers and the scientific community.

APPROACH

Overall Objective: Design, develop and evaluate the performance (weed suppression, crop quality and yield), ecological (soil impacts), and economic impacts associated with using biodegradable composite hydromulches in organic horticultural production systems.Our overall objective will be accomplished with a series of sub-objectives. First, we will develop new alternative composite hydromulches and develop application methods suitable for various production systems. Experiments will be conducted to assess physical properties of hydromulches composed of various materials. Weed suppression action of the mulches will be tested in a greenhouse by applying measured amount of hydromulch to trays of soil containing weed seeds and the weed emergence will be quanitifed. While the hydromulch formulation are being developed, project personnel will work on developing effective and efficient field-scale hydromulch application techniques. Next, initial field experiments will be conducted to evaluate hydromulch performance with respect to weed suppression and crop performance in annual day-neutral strawberry production (WA and ND). Several hydromulch formulations will be applied to beds containing day-neutral strawberries and mulch effects on weed emergence, yield and fruit quality, crop nutrition, and soil attributes will be assessed. Then, more comprehensive experiments will be conducted in blueberry (WA) and transplanted vegetables (ND and MN). These experiments will evaluate hydromulch performance with respect to weed suppression, crop performance, and impacts on soil variables, including soil health. Finally, we will assess the economic benefits of hydromulch use and conduct extension activities to inform producers about the benefits of hydromulching for organic fruit and vegetable production (See Table 1 below for a visual timeline for all project sub-objectives).Table1. Timeline of planned project activities.December to FebruaryMarch to MayJune to AugustSeptember to November2021Proposal submitted 1/14/21Formulation developmentApplication tech development2022\-- Formulation development (MSU) and evaluation (NDSU) \-- Application technology development (WSU, NDSU, farmers) \--Data analysesEvaluate preliminary hydromulches in strawberry production (WSU and NDSU)2023Formulation testingEvaluate hydromulches in blueberry (WSU) and vegetable (NDSU) productionApplication tech refinementSoil measurements in blueberry and vegetable studies (USDA-ARS)2024Analyze data, economicsEvaluate hydromulches in blueberry (WSU) and vegetable (NDSU) productionPresent Initial ResultsSoil measurements in blueberry and vegetable studies (USDA-ARS)2025Analyze data, economicsFinal soil measurements in blueberry and vegetable studies (USDA-ARS)\-\-\-\-\-\-\-- Data analyses, extension, manuscript preparation (WSU, NDSU, MSU, USDA-ARS) \-\-\-\-\-\-\-- Progress 09/01/23 to 08/31/24 Outputs Target Audience:The target audiences for this project, relevant to the current reporting period, are the following: 1. Producers and growers interested in non-chemical weed management in specialty crops such as broccoli and blueberry, or other horticultural crops. 2. Extension educators who work with the above growers. 3. The scientific communities interested in non-chemical weed management in horticultural production systems. Changes/Problems:Because we planned additional field trials outside the scope of the original project, and to provide more time for analyzing and disseminating data (especially econonic and soil health data) we applied for and received a no-cost extension for this project to continue until 8/31/2026. What opportunities for training and professional development has the project provided?The project has provided training opportunities for graduate students and a postdoctoral associate to engage in multidisciplinary, cross institutional research and communicate their findings across a broad range of audiences. How have the results been disseminated to communities of interest?A peer-reviewed research article reporting results relative to sub-objective 1 was published (see \'products\' section in this report, doi.org/10.1016/j.indcrop.2024.119349). A peer-reviewed research article reporting the project results relative to sub-objective 3 was published (see \'products\' section in this report, doi.org/10.3389/fagro.2024.1375505). A peer-reviewed review article about alternative and emerging mulch technologies, including hydromulch, was published (see \'products\' section in this report, doi.org/10.21273/HORTSCI18029-24). This paper will educate the broader scientific community regarding the importance of mulch and new mulch technologies that have the potential to be biodegradable and compatible with organic production. Multiple presentation to report and share results were delivered by project investigators and/or their graduate students (see \'products\' section in this report). These included, field days, grower conferences, and scientific conferences. Information about the project was shared by project investigators via three podcasts and one YouTube video (see \'other products\' section in this report). Multiple presentations were made at field days as well as grower and academic conferences. News about the project was also shared via eOrganic website and associated updates (see \'products\' section in this report). What do you plan to do during the next reporting period to accomplish the goals?For the onion field trial,

we will prepare a report discussing the net benefits of hydromulch application for each treatment, and the conditions under which the use of hydromulch is economically viable for growers. A similar analysis will be done for the blueberry field trial. For the blueberry field trial, we will analyze fruit quality data and share pertinent data to our economist for cost-benefit analysis. Final soil health data will be collected spring 2025, analyzed, and shared via presentations at academic and grower events as well as a peer-reviewed publication. At Fargo, we plan to conduct a final set of field trials to directly document crop impacts of incorporating hydromulch material into the soil for two years. We will plant onions under plastic mulch in every plot to directly measure any crop impacts from hydromulch. Impacts What was accomplished under these goals? Sub-Objective 1: Additional greenhouse trials were conducted in Washington to determine if adjusting hydromulch thickness and material properties could suppress nutsedge (Cyperus rotundus). The results of the trial indicate none of the evaluated thicknesses and hydromulch formulations are superior in the suppression of nutsedge. Sub-Objective 2: Established applications methods were used to conduct new hydromulch field trials. We continued to refine established approaches. Sub-Objective 3: These studies have been completed. Results and project insights have been presented at several scientific conferences and field days. Results have also been synthesized into two peer-reviewed publications, one of which has been published and one of which is under review. Results showed that hydromulches with a guar gum tackifier performed best among hydromulches in terms of weed suppression, but polyethylene (PE) film mulch provided superior weed suppression. However, hydromulches with guar gun tackifiers often protected fruit yield as well as PE film mulch in spite of allowing some weed emergence. This result is likely due to other factors besides weed control related to soil microclimatic control. Sub-Objective 4: The blueberry trial initiated in spring 2023 was continued for a second year in 2024 in a commercial field of \'Valor\' blueberry in Prosser, WA.In ND, hydromulches were applied and assessed within a broccoli production system. During 2023, GG and CM (3% and 6%) HMs were evaluated in onion (Highlander) crop against white-on-black PE film and weedy/weed-free checks (WC/WFC) at Absaraka and Fargo, ND. HMs were applied at rate of 5765 kg total dry matter hectare-1. PE mulch had zero weeds at peak weed emergence (PWE) and peak weed vegetative growth (PWVG) at both sites. Hydromulch with 6% GG controlled weeds best among HMs at PWE (10 weeds m-2) and PWVG (12 weeds m-2). Weed biomass was reduced the most in 6% GG (118 g m-2) compared to WC (748 g m-2). PE and GG showed similar mulch deterioration (both 0%) at Fargo, ND. Onion yield was greatest for PE (58,808 kg hectare-1) but was statistically similar to 6% GG (38,113 kg hectare-1). Overall, HM with 6% GG can be an effective alternative to PE for organic onion production. At WA during 2023, HMs were compared to woven PE mulch (\'weedmat\') in northern highbush blueberry (Vaccinum corymbosum \'Valor\'). HM treatments at WA included recycled paper with or without 4% GG and a pre-mixed paper slurry with 4%GG. In blueberry, weed suppression varied by treatment, with weedmat providing nearly full suppression of all weeds. Tackifier added to recycled paper improved dicot suppression. None of the hydromulch treatments effectively suppressed monocots (mostly nutsedge). Yield and fruit quality the same across all treatments. Soil health measurements were made for all field trials.Soil nitrogen mineralization was measuredthroughout the field season inboth blueberry and broccoli. Soil health processing is up to date for nutrients, and microbial activity. Chemical analyses of stored microbial biomass extractions from the prior year are now up to date following needed maintenance and calibration of analytical equipment. Similarly processing of community profiling has started for current and stored samples after appropriate modifications to protocols were made and applied. We were able to present the microbial activity and a portion of the nitrogen mineralization data at a summer meeting (see presentation/abstract list. To date the microbial activity data does not indicate that use of paper-based hyromulches has negative impacts on either blueberry or onion production systems. Rather, the activity suggests that the mulch in some cases may contribute to activity and in others correlates with a decrease in weed pressure and thus decrease in root exudates that often cause increased turnover of nutrients. Data and results from these trials were presented at various conferences and field days. Sub-Objective 5: For each hydromulch treatment in the onion field, we have completed the following: (1) Compiled cost estimates associated with producing the hydromulch material; (2) Used the prevailing wage rate in North Dakota as of 2024 to estimate the labor costs for applying the hydromulch; and (3) Estimated the market price of onions that is required for the gross revenue from the hydromulch treatment to be equal to that of control treatment (PE mulch). Sub-Objective 6: A peer-reviewed research article reporting results relative to sub-objective 1 was published (see \'products\' section in this report, doi.org/10.1016/j.indcrop.2024.119349). A peer-reviewed research article reporting the project results relative to sub-objective 3 was published (see \'products\' section in this report, doi.org/10.3389/fagro.2024.1375505). A peer-reviewed review article about alternative and emerging mulch technologies, including hydromulch, was published (see \'products\' section in this report, doi.org/10.21273/HORTSCI18029-24). This paper will educate the broader scientific community regarding the importance of mulch and new mulch technologies that have the potential to be biodegradable and compatible with organic production. Multiple presentation to report and share results were delivered by project investigators and/or their graduate students (see \'products\' section in this report). These included, field days, grower conferences, and scientific conferences. Information about the project was shared by project investigators via three podcasts and one YouTube video (see \'other products\' section in this report). Multiple presentations were made at field days as well as grower and academic conferences. News

about the project was also shared via eOrganic website and associated updates (see \'products\' section in this report). Publications Type: Peer Reviewed Journal Articles Status: Accepted Year Published: 2024 Citation: Ahmad W, DeVetter LW, McFadden D, Maupin B, Bajwa DS, Durado A, Weyers S, Galinato SP, Weiss B and Gramig G (2024) Hydromulches suppress weeds and maintain fruit production in organically managed strawberry systems. Front. Agron. 6:1375505. doi: 10.3389/fagro.2024.1375505 ORCID ID Lisa Devetter = 0000-0002-4412-385X ORCID ID Greta Gramig = 0000-0003-2791-282X Type: Peer Reviewed Journal Articles Status: Accepted Year Published: 2024 Citation: Shcherbatyuk, N., Wortman, S. E., McFadden, D., Weiss, B., Weyers, S., Ahmad, W., Bajwa, D. S., Galinato, S. P., Formiga, A., Gramig, G., & DeVetter, L. W. (2024). Alternative and Emerging Mulch Technologies for Organic and Sustainable Agriculture in the United States: A Review. HortScience, 59(10), 1524-1533. Retrieved Nov 5, 2024, from https://doi.org/10.21273/HORTSCI18029-24 ORCID ID Lisa Devetter = 0000-0002-4412-385X ORCID ID Greta Gramig = 0000-0003-2791-282X Type: Peer Reviewed Journal Articles Status: Accepted Year Published: 2024 Citation: Andrew Durado, Dilpreet S. Bajwa, Greta Gramig, Sharon Weyers, Lisa Wasko DeVetter, Alice Formiga, Suzette Galinato, Biodegradable composite hydromulches for sustainable organic horticulture,Industrial Crops and Products,Volume 221,2024,119349,ISSN 0926-6690,https://doi.org/10.1016/j.indcrop.2024.119349. ORCID ID Lisa Devetter = 0000-0002-4412-385X ORCID ID Greta Gramig = 0000-0003-2791-282X Type: Theses/Dissertations Status: Published Year Published: 2023 Citation: Durado, Andrew. 2023. Thesis: Biodegradable composite hydromulches for sustainable organic horticulture. https://scholarworks.montana.edu/handle/1/17858 Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Bajwa, D. 2024. Moisture characteristics of biodegradable composite hydromulches for sustainable organic horticulture. The 35th Annual Meeting of the Association for the Advancement of Industrial Crops. Lisbon, Portugal. Type: Other Status: Published Year Published: 2024 Citation: Formiga, A. 2023. Learn more about mulch! eOrganic Updates. November 2023. Available at https://eorganic.org/node/35751 Type: Other Status: Published Year Published: 2024 Citation: Formiga, A. 2024. Hydromulch research updates. eOrganic Updates. April 2024. Available at https://eorganic.org/node/35968 Type: Other Status: Published Year Published: 2024 Citation: Formiga, A. 2024. New Hydromulch video. eOrganic Updates. June 2024. Available at https://eorganic.org/node/36029 Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Weiss, B. 2023. All About Mulch. Comox Valley Horticultural Society. Zoom talk (Courtenay, BC, CA.) Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Weiss, B. 2023. MulcH2O: A biodegradable, certifiably organic mulch technology. Washington Small Fruit Conference. Lynden, WA. Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Weiss, B. 2024. MulcH2O: A biodegradable, certifiably organic mulch technology. Organic Crop Improvement Association (OCIA). Zoom talk (Lincoln, NE.) Type: Other Status: Published Year Published: 2024 Citation: Formiga, A. 2024.Alternative and Emerging Mulch Technologies for Organic and Sustainable Agriculture in the United States: A Review. eOrganic Updates. September 2024. Available at https://eorganic.org/node/36132 Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Hydromulches Enhance Weed Management and Crop Yield in Organic Onion Production. Waqas Ahmad,Sharon Weyers, Benjamin Weiss, Lisa Wasko DeVetter, Andrew Durado, Dilpreet Bajwa, Suzette P. Galinato, Alice Formiga, Greta Gramig; Western Society of Weed Science 2024 Annual Meeting, Denver CO, March 4-7 (77) Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Weiss, B. 2024. All about mulch. Western Cascade Fruit Society. Bremerton, WA. Weiss, B. 2024. MulcH2O: A biodegradable, certifiably organic mulch technology. Cloud Mountain Farm Center field day. Everson, WA. Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Weiss, B. 2024. MulcH2O: A biodegradable, certifiably organic mulch technology. Rodale Institute field day. Rockport, WA. Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Devetter, Lisa W. 2024. MulcH2O: A biodegradable, certifiably organic mulch technology. Northwestern Washington Research and Extension Center mulch field day. Mount Vernon, WA. Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Ahmad, W. and Gramig, G. 2024. Hydromulches for weed suppression in broccoli. Plants, Local Foods & Outdoor Spaces Conference. NDSU Horticulture Research and Demonstration Gardens. July 30, 2024. Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Ahmad, W. and Gramig, G. 2024. Hydromulches for weed suppression in broccoli. NDSU Fruit, Hemp, Vegetable and Woody Plant Field Day. NDSU Horticulture Research Farm and Arboretum. September 5, 2024. Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Gramig, G. 2024. Nonchemical Weed Management Research Updates: MulcH2O: Biodegradable Composite Hydromulches . NDSU Wild World of Weeds Workshop. Fargodome, Fargo, ND. January 16, 2024. Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Ahmad, W. 2024. Hydromulches as a weed control alternative to plastic mulches for organic agriculture. Roots and Rhizomes: Growing Together Marbleseed Annual Conference. Organic Research Forum. LaCrosse, WI. February 29 - March 2, 2024. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Weyers, S. L., Gramig, G. G., DeVetter, L. W., Morales, E., Ahmad, W., Weiss, B., Maupin, B., Bajwa, D., Galinato, S., & Formiga, A. (2024) Soil Health Under Hydromulches Applied for Weed Control \Abstract\. SSSA 2024 Summer Conference, San Juan, PR.

https://scisoc.confex.com/scisoc/2024sssa/meetingapp.cgi/Paper/156520 Progress 09/01/22 to 08/31/23 Outputs Target Audience:The target audiences for this project, relevant to the current reporting period, are the following: 1. Producers and growers interested in non-chemical weed management in specialty crops such as onions and blueberry, or other horticultural crops. 2. Extension educators who work with the above growers. 3. The scientific communities interested in non-chemical weed management in horticultural production systems. Changes/Problems:Due to different soil structural parameters following the rotary tillage and bed shaping of vegetable beds at the North Dakota research sites, including the potential for flooding of fields, the open-chamber resin N mineralization method was replaced for the winter assessment period by the buried bag method - whereby intact soil cores were placed in sealed ziplock bags and buried under the soil surface until retrieval in the spring. Ziplock bags allow for gas exchange but prevent leaching of nutrients from the incubating cores. Our literature review publication submission to peer review was delayed as the student originally working on the paper departed, but the manuscript is still in preparation and will be submitted during the next reporting period. What opportunities for training and professional development has the project provided?This project has provided training and professional development opportunities for graduate students Ben Weiss (MS student), Waqas Ahmad (PhD student), and Andrew Durado (MS student). These students were trained in responsible conduct of field and laboratory research, organic regulations and farming as pertaining to mulching and various mulch materials, and oral and written scientific communication to diverse audiences including farmers, crop consultants, and scientists. Under Sub-Objective 4, opportunities were presented to two graduate students and other field technicians to learn techniques of field soil mineralization measurements, and soil sampling and processing procedures. How have the results been disseminated to communities of interest?Project results have been disseminated to relevant stakeholders and communities of interest via numerous presentations given via scientific conferences, field days, grower conferences, newsletters, trade journals, extension publications, and one webinar as detailed in the \'other products\' section of this report. What do you plan to do during the next reporting period to accomplish the goals?Objectives 1 and 2 are complete, except for associated peer-reviewed publications, which will be completed during the next reporting period. Objective 3: We plan to publish two papers summarizing the results of the strawberry field experiment as well as a literature review. Objective 4: We will complete the blueberry and vegetable field studies, along with associated soil health analyses. During the next reporting period a second year of soil health analyses and in-field nitrogen mineralization measurements will be undertaken. Graduate students and technicians will have to opportunity to learn the laboratory-based methods to soil health analyses. Objective 5: During the next reporting period, we will conduct a preliminary assessment of costs associated with the application of hydromulch (including materials and labor). We will also collect data to develop baseline production costs of organic onion and broccoli in North Dakota. Objective 6: We will continue to disseminate project information including impacts of hydromulch on horticultural, weed management, soil health, and economic variables. Several peer-reviewed publications to disseminate project results will be submitted and accepted during 2024. A webinar to share major project results and concepts will be presented during 2024. Impacts What was accomplished under these goals? Sub-Objective 1: Design and develop biodegradable composite hydromulch formulations; evaluate hydromulch formulation impact on weed suppressive ability in a controlled environment. The majority of the work for this objective was completed during the last reporting period. However, two new materials, hemp hurd and camelina meal, were evaluated for use in organic hydromulch formulatuons. Soil adhesion and moisture tests (% moisture and water angle) were performed on hydromulch samples. The physical and mechanical properties data was statistically analyzed. The results of these additional assessments informed the choice of mulch formulation treatments for Objective 4. One graduate student completed an MS thesis based on Sub-Objective 1 experiments. Sub-Objective 3: Evaluate hydromulch efficacy and impact on crop quality and yield in annual day-neutral strawberry production systems. The experiment associated with Sub-Objective 3 was completed in Washington and North Dakota and two scientific papers are in preparation. Results were presented during Sub-Objective 4: Evaluate hydromulch efficacy and impact on crop quality and yield and soil health indicators (in perennial blueberry production and in annual market vegetable production. An experiment was established at a commercial blueberry operation in Prosser, Washington. Three hydromulch formulations were evaluated alongside a non-biodegradable plastic mulch control. Plant growth, yield, berry quality, mulch performance, weed suppression, and soil health data were collected and the experiment will be repeated in 2024. Another experiment was established at operation at research sites located in Fargo and Absaraka ND. Four hydromulch formulations were evaluated alongside a non-biodegradable plastic mulch control as well as weedy and weed-free checks. Plant growth, yield, berry quality, mulch performance, weed suppression, and soil health data were collected and the experiment will be repeated in 2024. Substantial progress was made towards achieving goals of Sub-Objective 4: Evaluate hydromulch efficacy and impact on crop quality and yield and soil health indicators in perennial blueberry production and in annual market vegetable production. Sequential in-field mineralization incubations were performed during both onion (North Dakota) and blueberry production seasons. Mineralization incubations were placed this fall to determine activity during the winter until sequential tests resume the next growing season. Soils have been processed to measure microbial biomass and activity, soil moisture content, and selected biochemical properties. Field methods addressed water

infiltration, continuous soil moisture content and temperature, and precipitation. Sub-Objective 5: Assess the economic impacts of hydromulch applications in the organic production of blueberry, onion, and broccoli via cost-benefit analyses. Organic blueberry enterprise budgets in WA have been updated and submitted for publication as WSU Extension Technical Bulletins. These production cost studies will be used as baseline for the cost-benefit analysis of hydromulch use. Sub-Objective 6: Conduct outreach and extension activities to disseminate results to stakeholders, including organic farmers and the scientific community. Information was shared at local- and statewide training events as well as at regional and national conferences. Trade journal and newsletter articles were also published. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Ahmad W, Bajwa D, Wasko DeVetter L, Durado A, Formiga A, Galinato S, Maupin B, McFadden D, Weiss B, Weyers S, and Gramig G. 2023. Cellulosic biodegradable mulches suppress weeds and maintain strawberry yield in diverse environments. American Society for Horticultural Science Annual Meeting, Orlando, FL. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Gramig G, Ahmad W, Bajwa D, DeVetter L, Durado A, Formiga A, Galinato S, Weyers S. 2023. Liquid-applied cellulosic mulches for weed suppression in day-neutral strawberry. Western Society of Weed Science Annual Meeting, Boise ID. (116) Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Durado AD, Bajwa DS, Gramig G, DeVetter LW, Weyers S, Formiga A, Galinato A, W. Ahmad W, and Weiss BD. 2023. Biodegradable composite mulches for sustainable organic horticulture. Association for the Advancement of Industrial Crops 34th Annual Meeting, Corvallis OR. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Weiss, B., L.W. DeVetter, W. Ahmad, and G. Gramig. 2023. MulcH20: An emerging soil-biodegradable mulch technology for organic strawberry production. American Society for Horticultural Science Annual Conference. Orlando, FL. Oral presentation. Type: Theses/Dissertations Status: Published Year Published: 2023 Citation: Andrew Durado. 2023. Biodegradable Composite Hydromulches for Sustainable Organic Horticulture. A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering. Montana State University. Type: Websites Status: Other Year Published: 2023 Citation: https://eorganic.info/node/35506 **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:Our main target audience is organic farmers who produce horticultural crops, specifically those crops that are typically grown using plastic mulch for weed management and environmental modification. Another target audience is agricultural scientists and extension personnel who would be interested in biodegradable alternatives to plastic mulches. Changes/Problems: Exceptionally wet spring and early summer field conditions during 2022 at ND and WA sites delayed establishment of the field trials associated with subobjective 3. Nevetheless, these field trials were eventually successfully established and the late start had minimal impacts on the experimental objectives, aside from possibly reduced strawberry yield associated with late planting at the ND site. Originally, the NDSU team had planned to conduct research associated with subobjective 4 on-farm, at a certified organic site managed by project collaborator and producer, Bjorn Solberg. The team visited the site during summer 2022 to conduct preliminary soil tests to inform future fertilization. These soil tests revealed extremely high levels of soil nitrate that would negatively impact the research. Subsequently, PI Gramig was informed by Mr. Solberg that 100K pounds of potato culls had been dumped on the field, something which had not been mentioned during the planning stages of the project. Consequently, will be unable to use this site for upcoming planned research. Instead we will use certified organic plots on the NDSU campus. Thischange has been approved by the NIFA program leader. The majority of the funds origninally allocated to Mr. Solberg' contribution will be re-budgeted to recoup some budget cuts made to our intitial request by NIFA. The PhD student working under Dr. DeVetter at WSU discontinued his program of study in August 2023. A new student will be hired soon, and impacts to the project will be minimal. We expect only minor delays analyzing data from subobjective and writing a literature review, an effortthat the former PhDstudent was spearheading. What opportunities for training and professional development has the project provided? This project has provided opportunities to train and professionally develop two PhD graduate students and one M.S. student. These students gained experience conducting research and presenting research results to extension and professional audiences. How have the results been disseminated to communities of interest? OSU co-PI Alice Formiga created a public website for the project on the eOrganic platform at <https://eorganic.info/hydromulch>. The website describes the project objectives, lists the collaborators, and provides photos, videos, research updates, and links to more information and publications about hydromulch.A summary of the research in 2021-2022, with photos, which is available on the website at https://eorganic.info/node/35506, was also sent in the June 2022 eOrganic newsletter. Results were presented at the following professional and extension events: McFadden, D., and L.W. DeVetter. 2022. Introduction to Hydromulches. Dort University Eco-Ag Field Trip. July 19, 2022. Mount Vernon, WA. (n=15 people) McFadden, D., and L.W. DeVetter. 2022. What is a Hydromulch? Washington State Commission of Pesticide Registration Tour. July 26, 2022. (n=50 people) Ahmad, W., and G. Gramig. 2022. Hydromulches for Weed Suppression in Day Neutral Strawberry. North Dakota State University Absaraka Horticultural Research Field Day. September 15, 2022. (n=35 people) Durado, A., Bajwa, D., and G. Gramig. 2022. Biodegradable Composite Hydromulches for Sustainable Organic Horticulture.33rd Association for the Advancement of Industrial Crops Meeting, Oct 9-12, 2023, Bozeman, MT. (n=45 participants) WSU co-PI Lisa DeVetter released tweets to publicize the project viaher

Twitter account, Lisa DeVetter@Mulch_Matters.One tweet made May 23, 2022 about the hydromulchapplication system received4,836 impressions. A newletter was published by WSU personnel to disseminate information about the project: McFadden, D. and L.W. DeVetter. 2022. Introduction to Hydromulch. Sustainable Mulch Management. May 2022.https://smallfruits.wsu.edu/plastic-mulches/newsletter/ What do you plan to do during the next reporting period to accomplish the goals? Subobjective 1: Although we made substantial progress developing hydromulch formulations, the team at MSU is still finishing assessment of formulations. Once this phase is complete, we anticipate a manuscript to be submitted for peer review in early 2023, and results will be presented at a professional conference. Also, we will be conducting additional greenhouse trials during winter 2023 to assess hydromulch formulations and rates to inform conducting subobjective 4. Subobjective 2: Application technology progressed enough to allow successful field application of hydromulch, but the system needs to be refined to minimize soil mixing with mulch during application, and to integrate the hydromulch application with crop planting. The NDSU team and farmer Ross Lockhart will continue work on application methods during spring/early summer of 2023. The WSU team will work on adapting application methods for commerical organic blueberry production. Subobjective 3: Data from this experiment will be analyzed, and results will be presented a field days and professional conferences during 2023. We anticipate preparing one manuscript for peer review from these results, to submitted during 2023. Subobjective 4: Field experiments to address this subobjective will be initiated during 2023 at WA and ND sites. Preliminary results will be reported at field days and professional conferences. Subobjective 5: All project team members will continue to collect data needed to complete economic analyses. Subobjective 6: Project progress will be described on the project's eOrganic webpage, and we will produce a webinar through eOrganic to share results with stakeholders during 2023. **Impacts** What was accomplished under these goals? Overall Objective: We have completed all planned objectives for this year, which will lead to accomplishing our overall objective. Subobjective 1: Several different composite hydromulch formulations were developed by co-PI Bajwa and his graduate student at MSU. They have conducted numerous tests to assess the physical properties of these hydromulches. During winter 2022, PI Gramig and her graduate student conducted greenhouse trials using these formulations to determine the best formulations and rates of application for initial field trials. Subobjective 2: Three separate groups (NDSU, ND producer Ross Lockhart, and WSU) evaluated different systems for preparing and applying hydromulches. These trials resulted in enough progress to allow successful application of hydromulches in field experiments. Subobjective 3: NDSU and WSU conducted field trials wherein five different hydromulch formulations (at a standard rate) were tested against standard black plastic mulch in a day neutral strawberry production system. Samples are currently being processed, and data prepared for analyses. Subobjective 4: This objective is planned for 2023 to 2025. In preparation, the team at NDSU tilled sites, sampled soil for nutrients, and built raised beds. Subobjective 5: A template that describes the data needed for the economic analysis has been developed and shared with project team members. These data will be used to estimate the costs of hydromulch formulation, and to compare the net benefits of using hydromulch relative to standard mulching practice. Data related to economic analyses were collected in the process of conducting activities related to subobjectives 1, 2, and 3. Subobjective 6: A website was created to share results of the project (https://eorganic.info/hydromulch). A summary of the research in 2021-2022, with photos, which is available on the website at https://eorganic.info/node/35506, was also sent in the June 2022 eOrganic newsletter. **Publications**

↑ Return to Index

Performance and Economics of Electric Weed Control in Organic Perennial Crops: a Multiregional Approach

Accession No.	1026745
Project No.	ORE01008
Agency	NIFA ORE\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34911
Proposal No.	2021-02933
Start Date	01 SEP 2021
Term Date	31 AUG 2024
Grant Amount	$2,044,595
Grant Year	2021
Investigator(s)	Moretti, M.; Hanson, BR, D.; Formiga, AL, K.; Sosnoskie, LY, M..; Brewer, LI, J..; Goodrich, BR, .; Chernoh, ER, .

NON-TECHNICAL SUMMARY

This project will consider the performance, safety, and economic and environmental sustainability of electric weed control (EWC) in perennial crops. Weed management is a significant constraint in organic orchard and berry production, due to limitations on crop rotation and between crop tillage. Organic weed control requires frequent soil disturbance, hand labor, high rates of organic herbicides, or the application of large amounts of organic or synthetic mulches. These factors can be barriers to economic, soil health, and sustainability goals. EWC could simultaneously address several of these challenges in the US high value organic perennial cropping sector. We have established four interlinked objectives in three key US production regions for bushberry and orchard crops: (i) developing site- and weed-specific recommendations for EWC, (ii) describing the long-term impact of electric weeder use on weed population, plant growth, soil health indicators, and labor in perennial crops, (iii) conducting cost and profitability analysis of EWC in tree and berry systems, and (iv) and engaging stakeholders via diverse approaches, including local and national efforts through eOrganic. A stakeholder advisory committee of organic growers and distributors, and scientific advisors will engage the industry at multiple levels and help develop educational tools for EWC. We expect EWC to improve weed management and system sustainability in a range of organic perennial crop systems in three key production regions.

OBJECTIVES

Objective 1: Develop site- and weed-specific recommendations for electric weed control. Objective 2: Determine the impacts of electric weed control on weed populations, crop vigor and productivity, and soil health in-crop. Objective 3: Perform cost and profitability analyses of electric weed control in bushberry and orchard crops. Objective 4: Extend results to stakeholders and describe changes in grower knowledge about and interest in electric weed control.

APPROACH

Objective 1We will conduct field experiments in certified fields to characterize EWC efficacy on key weed species affecting perennial crops in California, Oregon, and New York. Treatment combinations will be replicated in space and the studies repeated in time. Select weed species will highlight the interaction of plant biology and edaphic

properties on EWC performance. Timing of EWC operations will occur relative to weed developmental stage and soil moisture will be recorded. Objective 2Treatment establishment: Replicated trials will be conducted at certified fields located on University property in Oregon, New York, and California. Highbush blueberry cv \'Duke\' will be planted in all spaced at 0.75 m in row and 3.3 m between rows and surface-amended with 2 cm compost and drip irrigated. Alleys will be planted with permanent grass cover. Three mulch treatments will be evaluated: a sawdust amendment for weed suppression, a geotextile synthetic mulch, and compost-only treatment as a reference. We selected three weed management systems to study EWC impacts. A 20% plot coverage weed threshold: Zero threshold: EWC will be applied throughout the season to ensure no weeds set seeds. Standard practice: To include mowing, hand-weeding, and spot-spraying weeds as needed. Plant growth and development evaluation: Canopy volume will be estimated by measuring plant at the beginning of the study and before leaf senescence at the end of every season. One plant per plot will be netted to collect all leaves, a subsample of which will be dried, weighed and recorded along with leaf area. At the end of three years, one plant per plot will be removed and its root system volume will be calculated. Plants will be segmented into new growth, mature wood, crown, and root, and weighed while fresh. Weed assessment: Weeds will be identified to the species level, and control per species assessed monthly. Weed cover and weed presence will be recorded thrice per year. Soil health and plant nutrition review: Baseline soil samples will be collected at establishment and immediately following EWC to assess short-term impacts on soil microbiology. Soil will be sampled yearly thereafter. Samples will be analyzed for biological, chemical and physical indicators of soil health. Leaf tissue samples will be collected yearly and subjected to chemical analysis of macro- and micro-nutrients. Labor and materials: All expenses and labor required will be recorded to the nearest second. We will evaluate the efficacy and safety of EWC in sweet cherry (OR), apple (NY) and almond (CA) crops. Objective 3: Perform cost and profitability analyses of electric weed control in bushberry and orchard crops. Update cost of production information for bushberry and orchard crops. Evaluate profitability of weed management strategies outlined in Objective 2. Objective 4: Use local and national efforts to extend results to stakeholders and describe changes in grower knowledge about and interest in electric weed control. Local efforts will focus on talks, field days and discussion groups. The eOrganic platform will be the focus of national efforts. Webpage for this project and eOrganic newsletter will publicize all activities to over 12,000 subscribers. Facebook, Twitter, and Instagram. Instructional videos will demonstrate EWC use. Project grower-cooperators and advanced on-farm studies instructional videos will be posted to the eOrganic Youtube channel with over 12 thousand subscribers and more than 3.5 views. Develop new extension materials related to weed management in organic blueberry. Update teaching materials germane to an undergraduate organic production class. Progress 09/01/23 to 08/31/24 Outputs Target Audience: Producers Field men Packers and distributors of woody perennial high-value horticultural crops Researchers in woody perennial high-value horticultural crops Weed scientists Weed management industry specialists Tree fruit and berry producers Crop consultants Cooperative extension specialists Agricultural and horticultural research faculty/staff/graduate students State regulatory officials Members of the public at large Dr. Qu Dyong. Director General of the UN Food and Agriculture Organization Dr. Karen St. Germain and the leadership team from NASA Acres. Changes/Problems:The transformer for Cornell\'s Zasso Electroherb unit failed in June of 2024 as the field season was beginning. A new transformer is being delivered from Brazil and repairs will be conducted in fall of 2024. Trials will resume in October and November to investigate dormant season electrical weeding on perennial weed control. Formal trials will resume in spring/summer of 2025. The initial economicst for this project transitioned to another IHE, and we have brought in another UC Davis applied economist for objective 3. What opportunities for training and professional development has the project provided?Student degrees. Baccin, L.C. Ph.D student; Undergraduate students: Maxwell Voss, Madden Robertson (worked for summer and fall 2024 in the project). Events. Moretti, M.L and Baccin, L. C. 2024. Exploring electric weed control in organic blueberries. Lower Mainland Horticultural Conference. January 10, 2024, Abbotsford, BC, CAN. (0.5h, 200 participants) Baccin, L. C., and Moretti. M. L. Impact of Electricity on Soil Health and Weed Control in Blueberries. Poster Presentation at the Weed Science Society of America annual meeting: San Antonio, TX. 2024. Baccin, L. C., and Moretti. M. L. Yellow Nutsedge and Canada Thistle Response to Electricity and Mowing. Paper Oral Presentation at the Weed Science Society of America annual meeting: San Antonio, TX. 2024. Baccin, L. C., and Moretti. M. L. Crop Safety and Weed Control in Organic Highbush Blueberries Using Electrical Weeding. Paper Oral Presentation at the Western Society of Weed Science annual meeting: Denver, CO. 2024. Results of EWC trials on common summer weeds in California were reported as a poster presented in the 2024 annual meetings of the California Weed Science Society, the Western Society of Weed Science, and the Weed Science Society of America. Baccin, L. C., and Moretti. M. L. Weed Control in Organic Blueberries: How Electricity is Changing the Game! Weeders of the West. 2024. Baccin, L. C., and Moretti. M. L. \"Electric Weed Control in Organic Highbush Blueberry\". YouTube, uploaded by Marcelo L Moretti, 28 Mar 2024, Sustainability Field Day, June 2024 Corvallis, OR. Blueberry Field Day, July 2024 Aurora, OR. Field visit - October 29, 2024 - Boring OR. On-farm demonstration and grower interaction. Scheduled field visit 4,000 acres of organic blueberry - Jefferson, OR Nov 15, 2024. Training opportunities were provided to three technicians, and a graduate research assistant. Affiliated cooperative extension specialists and research support staff (i.e. farm managers, mechanics, electricians) have

also received instruction regarding unit operation, safety, and performance. Electrical weed control technology has been discussed as a part of four guest lectures (Cornell University, Finger Lakes Community College, Penn State, University of Wyoming) to 100 undergraduate and graduate students. Graduate student Tong Zhen attended the 2024 annual meetings of the Western Society of Weed Science and the Weed Science Society of America. He presented the EWC project as a poster. How have the results been disseminated to communities of interest? We have disseminated the results in person, online, and through trade articles for both academic and non-academic audiences. We are now preparing two scientific publications summarizing results from objective 1. Sosnoskie, L.M. Rooting for Robotics. The Crop Corner Podcast. October 17th, 2023. https://shows.acast.com/coffee-then-crops/episodes/652de5922bf6d100120ca69f Sosnoskie, L.M. On target for a weed control victory in vineyards. Growing Produce. December 11th, 2023. https://www.growingproduce.com/fruits/grapes/on-target-for-a-weed-control-victory-in-vineyards/ Sosnoskie, LM. After the volts: is electrocution safe for the soil? GROW IWM. April 9th, 2024. https://growiwm.org/after-the-volts-is-weed-electrocution-safe-for-the-soil/ Butler-Jones, A.L. Responses of weeds and microarthropod communities to Zasso electrical weeding. Presentation at the Northeastern Weed Science Society annual meeting. January 9th, 2024. Boston, MA. (200 participants) Sosnoskie, L.M. Novel weed control technology in grapes and perennial crops. Presentation for the Ontario Fruit and Vegetable Convention. February 22nd, 2024. Niagara Fall, ON, Canada. (70 participants) Sosnoskie, L.M. Novel weed control technology. Presentation in the New York Orchard Soil Health Webinar. February 26th, 2024. Geneva, NY. (60 participants) Sosnoskie, L.M. Novel weed in perennial crops: where do we stand and where are we going? Presentation in the New York Berry Weed Management Webinar. March 6th, 2024. Geneva, NY. (60 participants) Sosnoskie, L.M. Novel weed control technology. Presentation for the 2024 Connecticut Farm Winery Education Symposium. March 26th, 2024. New Haven, CT. (40 participants) Sosnoskie, L.M. Novel weed control technology. Presentation for Director General of the UN Food and Agriculture Organization, Qu Dyong. May 8th, 2024. Geneva, NY. (15 participants) Sosnoskie, L.M. Vision spraying and electrical weeding in perennial crops. Presentation at the Precision and Digital Viticulture Field Day. June 4th, 2024. Geneva, NY. (30 participants) Sosnoskie, L.M. Vision spraying and electrical weeding in perennial crops. Presentation at the Precision and Digital Viticulture Field Day. June 6th, 2024. Portland, NY. (40 participants) Butler-Jones, A.L. Responses of weeds and microarthropod communities to Zasso electrical weeding. Presentation at the Weed Management in Perennial Fruit Crops - Field Workshop. June 20th, 2024. Tivoli, NY. (30 participants) Butler-Jones, A.L. Responses of weeds and microarthropod communities to Zasso electrical weeding. Presentation at the Champlain Valley Orchard Weed Management Field Meeting. June 21st, 2024. Peru, NY. (30 participants) Sosnoskie, L.M. Novel technologies for weed management. 2024 Christmas Tree IPM Field Day. August 15th, 2024. (20 participants) Sosnoskie, L.M. The now and future of novel weed control. Presentation for NASA ACRES leadership #Space4Ag New York Tour. August 21st, 2024. Portland, NY. (40 participants) A demonstration of the Zasso machine on Weed Day 2024 received a lot of questions and discussions among California farm advisors, growers, weed specialists, and graduate students. The conversation has led to potential projects in the next reporting period, such as performing a grower\'s trial and collaborating with the UC farm advisor. An article about UC Davis Weed Day 2024 was published on the UC Davis Department of Plant Sciences website. https://www.plantsciences.ucdavis.edu/news/weed-day-2024. The same article was posted on UC Davis Plant Sciences Social Media & Newsletter as well. What do you plan to do during the next reporting period to accomplish the goals? The focus of the final funding year is to continue the study in Objective 2 (long-term study) and 3 (economic analysis) while publishing findings from objective 1. We expect that Luisa Baccin will conclude her Ph.D program in the fall of 2024 We will expand our extension activities, including a webinar on January 14, 2025. We are also organizing a Stakeholder Perspective and Engagement meeting to collect feedback on the project progress and future needs. We will complete an additional year of trials in established organic apples comparing the performance and safety (crop and soil health) of electrical weeding to cultivation, as well as electrical weeding followed by cultivation (stacked tools). We have also planted a new apple (Honeycrisp on B9, B10, G11, M7 rootstocks) block/vineyard (own-rooted Concords and Seyvals on 3309 rootstocks) to describe the impacts of electrical weeding on weed control and tree and soil health to better describe the application potential of the technology in young trees and vines. UC Davis Team will continue to conduct experiments described in Objectives 1 and 2 described above and finish data analysis from the data collected in 2024. Graduate student, Tong Zhen, plans to draft two publications regarding Objectives 1 and 2 described above. Two publications will be completed by December 2025. For Objective 3, we plan to conduct a grower\'s trial in an organic prune orchard to analyze cost and profitability. Impacts What was accomplished under these goals? Objective 1: Oregon State conducted four replicated field studies in Jefferson OR and Grants Pass OR commercial blueberry fields to compare the effectiveness of electric weed control (EWC) on different weed species and at different times of the year. All trials used a large commercial unit (XPS Power) and a prototype suitable for small farms. Results suggest that multiple passes at higher speeds (\>2 mph) are more economical in the long term. The current prototype produces 3 kW and is most effective at one mph or slower speeds. Results indicate that EWC can control annual weeds and perennial weeds like Canada thistle, yellow nutsedge, and horsetail. Cornell: Early

season electrical applications were made to newly emerged Canada thistle and compared to flame weeding to describe the impacts on extended control. Additional trials were delayed until next year due to a mechanical failure in the transformer, which is currently being resolved. Davis: Electrical weed control (EWC) trials on different common summer weeds in California orchards. Field experiments of EWC to determine the relationship between weed control efficacy and soil water content in summer 2024. Obnjective 2: Studies at Oregon State on blueberry in Corvallis showed that while plastic mulch outperformed electricity or mowing, its benefits were limited to the base of the plant. Electricity treatments did not affect soil health or plant growth. Electric weed control is compatible with all types of soil mulches, and the number and species diversity of weeds were greatly reduced by the electricity treatments compared to mowing or nontreatment. Our nontreated plots indicate that lack of weed control causes significant plant death (30%) and growth reduction. At Cornell, apple trees treated in the 2023 trials were monitored for survivability, leafing out/canopy development, and other phenology differences in 2024. Data is being analyzed. 2024 research trials could not be conducted because of a broken transformer in the Zasso Electro-herb unit, which is being repaired. Soil physical structure, chemical composition, microarthropod density and diversity, and microbial activity data derived from samples collected from the 2023 field season are being analyzed. In 2025, trials will be conducted to compare cultivation to electrical weeding with respect to soil health parameters. In 2023, an electrical weeding vs cultivation and hand weeding study was conducted in a newly planted apple nursery. Tree health (survivability, leafing out, growth and biomass accumulation) was evaluated following nursery stock removal from cold storage in spring of 2024. Results suggest electric weeding is safe for use in young trees, although differences were observed among root stocks. An apple orchard with Honeycrisp on B9, B10, G11, M7 rootstocks was planted in spring of 2024 to better elucidate the influence of rootstock and rooting behavior on crop safety. Concord grapes on their own-roots and Seyval grapes grafted onto 3309 rootstock were also planted to evaluate electrical weeding in young organic orchard and vineyard systems. The UC Davis Team continued conducting EWC crop safety trials in organic almond and blueberry orchards, which are in their second growing season. The first-year (2023 season) results from the almond trial were presented as posters at the 2024 annual meetings of the California Weed Science Society, the Western Society of Weed Science, and the Weed Science Society of America. Objective 3: The production budget for organic blueberries is being revised and improved with the expected conclusion in the spring of 2025. Dr. Daniel Sumner, UCD, is leading the economic analysis for the project since Dr. Goodrich accepted a different role. Objective 4: A website was created for the project: https://eorganic.info/node/35641 Youtube video: https://youtu.be/a_HHKVHeMjw?si=w4Qxnrpj8NmD0_KQ website. Link:https://eorganic.info/node/35946 Results from field trials were shared with more than 600 stakeholders in the US and Canada via in-person presentations and webinars. Additional outreach was achieved via The Crop Corner podcast, and features in the GROW IWM website and Growing Produce magazine. A demonstration of EWC was presented on 2024 Weed Day at UC Davis on June 26, 2024. Publications Progress 09/01/22 to 08/31/23 Outputs Target Audience: Producers Field men Packers and distributors of woody perennial high-value horticultural crops Researchers in woody perennial high-value horticultural crops Weed scientists Weed management specialists Changes/Problems:Blueberry Crop Safety Study Update: In our blueberry crop safety study in NY, the weed fabric treatment unfortunately resulted in the loss of over 50% of the plants. This loss was primarily due to excessive summer heat and the relatively small size of the young blueberries. To address this issue, we have decided to replant the mulch trial in September 2023, this time with larger plants. Furthermore, for the purpose of data analysis, we will separate the weed fabric treatment from the other mulch treatments, as they were introduced at different planting dates and involved varying plant sizes. Equipment Varieties in Oregon: In Oregon, our research involves the utilization of two distinct types of equipment. The first is the Zasso, which aligns with the equipment used by our collaborators in Objectives 1 and 2. The second equipment variant is a prototype designed for small farms. Given that the average blueberry farm size in Oregon is approximately 20 acres, and most growers do not possess tractors exceeding 40 horsepower, this prototype is tailored to their needs. Importantly, it requires around 25 horsepower and comes at a significantly lower cost, amounting to less than one-third of the price of a larger unit. Our efforts are concentrated on defining viable working speeds and operational costs for this specific type of equipment What opportunities for training and professional development has the project provided? Tong Zhen, a graduate student in the Hanson Lab, delivered a presentation titled \"Electrical Weed Control in Organic Orchards\" at the California Weed Science Society Annual Meeting in Monterey in January 2023. The presentation provided an overview of the mechanism behind electrical weed control and shared preliminary data and images of weed damage from a demonstration held in May 2022. The Hanson Lab conducted a live demonstration of electrical weed control in orchard crops during the 2023 Weed Day hosted by UC-Davis. The demonstration was aimed at growers, farm advisors, and professionals from the crop protection industry. Aleah Butler Jones, a graduate student in the Sosnoski Lab, presented preliminary results from the 2022 field season at the 2023 joint Weed Science Society of America and Northeastern Weed Science Society Annual Meeting. Her Single Slide Talk earned second place. Luisa Baccin, a PhD student, presented at both the WSWS in March 2023 and OSWS in October 2023. Additionally, a select group of growers visited the study site for one-on-one demonstrations. How have the results been disseminated to communities of interest? We have introduced electrical weed control in

California Weed Science Society and UC Davis Weed Day during this reporting period. We have exchanged ideas and interacted with field men in perennial high-value horticultural crops, and researchers in these crops, weed scientists and weed management specialists. Butler-Jones, A. L. (2023, January 31). Preliminary Responses of Weeds, the Weed Soil Seedbank, and Microarthropod Communities to Zasso Electrical Weeding \Oral presentation\. Weed Science Society of America - Northeastern Weed Science Society Joint Meeting, Arlington, VA, United States. Cornell will repeat the established orchard trial in the summer of 2024. Electrical Weed Control in Organic Highbush Blueberry. Luisa C. Baccin*, Marcelo L. Moretti; Oregon State University, Corvallis, OR (009) What do you plan to do during the next reporting period to accomplish the goals?Objective 1: Develop Site- and Weed-Specific Recommendations for Electric Weed Control Our research plan involves an expansion of our studies in both bare-ground and orchard settings, commencing in the fall of 2023 with a focus on winter annual weeds. These investigations will continue into the spring and summer of 2024, allowing for the collection of more comprehensive data encompassing various weed species and different orchard crops. Given the limited spring and summer rainfall in California, we have recognized the necessity for an irrigation and soil moisture study. This study will evaluate the effectiveness of electrical weed control under varying soil moisture conditions. We intend to employ various irrigation methods, including surface drip, subsurface drip, and micro-sprinkler systems to generate comprehensive weed control efficacy data during the spring and summer of 2024. Additionally, we are committed to sustaining our ongoing studies in commercial blueberry fields, with a specific emphasis on perennial weeds. These studies will continue to document the impact on vegetative propagules and seed production of yellow nutsedge and Canada thistle. Objective 2: Determine the Impacts of Electric Weed Control on Weed Populations, Crop Vigor and Productivity, and Soil Health in-Crop Hanson Lab: The almond and blueberry crop safety studies will persist into the spring of 2024. Orchard maintenance will resume during the winter of 2024. Sosnoski Lab: The Sosnoski Lab at Cornell, utilizing the Zasso Electroherb unit for electrical weed control, will repeat the study focusing on a combination of treatments, considering travel speed (1.7 and 4.8 kph) and mean amperage (9.1 A, 19.4 A, and 35.6 A). We plan to identify extracted microarthropods to the family level and report arthropod abundance as the number of individuals per kilogram of dry soil. The composition and relative abundance of the soil microbial community will be determined. Soil samples will undergo analysis for multiple indicators of soil health, including soil texture, aggregate stability, organic matter content, and pH, at the Cornell Soil Health Testing Laboratory. Moreover, we will assess the physical, chemical, and biological characteristics of the field trial in accordance with the soil sampling protocol outlined in the Cornell Comprehensive Assessment of Soil Health manual. After the final treatment application, soil samples will be collected for wet aggregate stability measurements. We will obtain five subsamples from each plot, aggregate them, and submit them for wet aggregate stability measurements. Our statistical analyses will be conducted in R Studio. We will use repeated measures ANOVA to analyze the effects of the management strategy on weed cover and total invertebrate abundance. Differences in microbial biomass and weed biomass will be determined using ANOVA. To reveal differences between treatment groups, Tukey\'s pairwise multiple comparison tests will be applied. We will also assess the effect of the weed management strategy on weed and soil biological communities through multivariate analyses. Lastly, our commitment includes the continuation of long-term studies and documenting their impact on yield, fruit quality, and gas exchange measurements in the plant. Objective 3: Perform Cost and Profitability Analyses of Electric Weed Control in Bushberry and Orchard Crops We are planning to conduct cost and profitability analyses of electrical weed control in blueberries and almonds during the 2024 growing season. Our analysis will involve a comparison of electrical weed control to other organic weed control methods, such as organic herbicides, hand-weeding, and cultivation. The evaluation will consider aspects of energy use efficiency and weed control efficacy. Objective 4. We will continue attending conferences and presenting our results. Impacts What was accomplished under these goals? Objective 1: Develop Site- and Weed-Specific Recommendations for Electric Weed Control At UC Davis, the Hanson Lab conducted replicated studies in two locations in Yolo County, California, to assess the impact of speed and power settings on weed control efficacy. These locations included a fallow field at the UC Davis Plant Sciences Field Facility in Davis and a 2-year-old walnut orchard at UC Davis Russell Ranch Sustainable Agriculture Facility in Winters, California. The fallow field study was initiated as a randomized complete block design with four replications in May 2023, featuring nine treatments, combining speeds (0.7 mph, 1 mph, and 1.3 mph) and power settings (high, medium, and low). The dominant weed species were field bindweed (perennial) and glyphosate-resistant hairy fleabane (established annual). Visual weed damage efficacy data was collected at 1 day after treatment (DAT), 3 DAT, 6 DAT, 13 DAT, and 21 DAT, with data analysis planned for September 2023. The walnut study was also initiated as a randomized complete block design with four replications in June 2023, featuring four treatments combining speeds (0.7 mph and 1.3 mph) and power settings (medium and low). The dominant weed species were common summer annuals, including hairy fleabane and tumble pigweed. Data collection for this study included visual weed damage efficacy and the number of regrowth at 5 DAT, 10 DAT, and 20 DAT, with data analysis scheduled for September 2023. The results of these studies will be presented at the California Weed Science Society Annual Meeting, the Western Weed Science Society Annual Meeting, and the Weed Science Society of America Annual Meeting in 2024. Objective 2: Determine the Impacts of Electric Weed Control on Weed Populations,

Crop Vigor, Productivity, and Soil Health New almond and blueberry plantings were established in a certified organic research field at the UC Davis Russell Ranch Sustainable Agriculture Facility in April 2023. A multi-season trial to assess the crop safety and soil health impacts of electrical weed control was initiated. For the blueberry crop safety study, two levels of treatments were considered: mulching types and weed control methods. Mulching types included weed fabric, sawdust, and bare ground. Electrical weed control treatments were applied at both high-power settings (traveling at 0.7 mph) and low-power settings (traveling at 1.3 mph) to evaluate the worst-case scenario\'s impact on crop and soil health in organic orchards. Electric weed control was applied in June and July 2023, with two more treatments scheduled for September and October 2023. Visual weed damage efficacy was evaluated at 5 and 10 DAT. After the 10 DAT evaluation of each application, all the weeds in each plot were removed to minimize weed-crop competition. Soil samples from both fields were submitted in June to the Cornell Soil Health Laboratory, with results pending. Plant height and stem diameter data for blueberries and almonds were collected in June 2023, with additional measurements planned for September 2023 and late October 2023. Objective 3: Perform Cost and Profitability Analyses of Electric Weed Control in Bushberry and Orchard Crops No experiments were conducted for Objective 3 in the current reporting period. Objective 4: Extend Results to Stakeholders and Describe Changes in Grower Knowledge and Interest in Electric Weed Control Electric weed control equipment was demonstrated at the UC Weed Day extension field day on June 21, 2023, for 100 pest control advisors and researchers from California. Several agricultural media reporters were present, further amplifying this extension effort through subsequent communications to their networks. A Blueberry Field Day attracted 175 growers in Aurora, Oregon, on July 15, NWREC. An OSWS presentation with 150 attendees included an oral presentation on October 24, 2023, by Luisa and Moretti. Additionally, a Blueberry Extension Day engaged 45 contacts with a presentation to growers on October 26, led by Moretti. Publications **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: Producers Field men Packers and distributors of woody perennial high-value horticultural crops. Researchers in these crops Weed scientists and weed management industry representatives Tree fruit and berry producers Extension specialists, Agricultural and horticultural research faculty/staff/graduate students State regulatory officials Members of the public at large Changes/Problems:The project was significant delayed in all states by supply chain issues including equipment manufacture, shipping, setup and crew training on the Zasso EWC. Some units were shipped to the east coast and freighted to the West coast. Moretti spend a significant amount of time overseeing ordering and shipping arrangements to ensure all research members had the necessary equipment. He also faced difficulties recruiting and retaining staff for this project, but it is now moving forward as planned. In California, an extremely dry winter and spring resulted in low weed growth and high fire risk. California field research will resume in fall and early winter when seasonal rainfall and temperatures stimulate germination and annual winter weed growth in almond and blueberry production. No significant changes to the project objectives or outcomes are expected from these delays. What opportunities for training and professional development has the project provided? OSU Research Associate Rafael Pedroso joined the project in October 2021 and was involved in experimental design and study implementation. He has since accepted a position elsewhere and left the project in July 2022. OSU PhD student Luisa Baccin joined the project in March 2022 and has been involved in project discussions, setup and training on the EWC equipment. Two additional graduate students not funded by this project have participated and seen EWC in action. Two undergraduate students have participated in field work related to this project. UC Davis PhD student Tong Zhen joined the project in Fall 2021 and has been involved in project discussions, setup and training on the EWC equipment, and initial demonstration and replicated experiments during spring 2022. In addition to Zhen, four additional graduate student and postdoc members of Hanson's team who are not funded by this project have also had opportunity to participate in UC Davis demonstration trials with the EWC. Cornell provided training to two technicians, two undergraduate summer scholars and two graduate research assistants. Affiliated cooperative extension specialists and research farm managers, mechanics, electricians have been instructed regarding unit operation, safety, and performance. How have the results been disseminated to communities of interest? Dissemination of results has been limited due to a cascade of delays related to supply chain issues. However, information about the project plans and goals has been shared with general audiences via the UC Weed Science blog, Cooperative Extension meetings, and in direct meetings with the target commodity groups in California. Electri-fried weed control trials underway: Oregon State University leads electric current project with potential for organic weed control in blueberries, apples and almonds. Good Fruit Grower, April 15, 2022 Issue. Two student poster presentations to student peers and the Cornell AgriTech community at large. New York Department of Environmental Conservation officials and members of Cornell University College of Agriculture and Life Sciences administration attended presentations/demonstrations. Stakeholders received project overview and preliminary results at the 2022 Peru Orchard Weed Management and Soil Health Field Day (July 20, \~25 attendees), the 2022 Lake Ontario Fruit Field Day (August 9, \~230 attendees), and the Cornell AgriTech 140th Anniversary Open House (August 13, \~800 attendees). What do you plan to do during the next reporting period to accomplish the goals?During the next reporting period, OSU will establish a \~1-acre planting of blueberry in a certified organic field for research proposed in Objectives 1 and 2. UC Davis will establish \~2-acre planting of blueberry and almond in a certified organic field for the same end. OSU will use a mature cherry

block for studies on the same objectives. Young plantings are crucial for evaluating the potential for negative crop safety and soil health impacts; the area around these plants will be treated with EWC multiple times per year for two growing seasons. Bare ground areas of the same field, as well as another certified field and conventional research fields will be used in related experiments to broaden the diversity of weed species evaluated. The EWC treatments and non-EWC alternatives at the UC Davis field location will also provide information on input costs, including hand labor, for the economic analyses proposed in Objective 3. Cornell has selected field sites and crop blocks for summer 2023 research trials to develop site- and weed-specific recommendations for electric weed control and to determine the impacts of electric weed control on weed populations, crop vigor and productivity, and soil health in-crop. A review article (New York Fruit Quarterly) describing the value of New York fruit and berry crops, major weedy pests, current weed management practices and the potential of electrical weed control in organic production operations is planned. Global health situation permitting, we anticipate including the EWC research in spring and summer field days in 2023. **Impacts** What was accomplished under these goals? Objective 1: Develop site- and weed-specific recommendations for electric weed control. Moretti group is meeting with statisticians at OSU to identify proper statistical analysis and design an experiment to compare performance of electric weed control across multiple sites. During this performance period, OSU activities have primarily been related to ordering, purchasing, receiving delivery, setup, and training on the EWC system for both Cornell and UC Davis. Both institutions had their equipment delivered in March 2022. Due to supply chain issues, there was a significant delay and increased equipment costs from the initial estimates. OSU has faced issues with tractor repair since June 2022. A second tractor was ordered but has not been received as of August 2022. To mitigate future delays, we have ordered additional front brackets to allow us to use three different tractors for this research as conditions dictate. We hope to have all system operation by early September 2022. During this performance period, UC Davis activities have primarily been related to ordering, purchasing, receiving delivery, setup, and training on the EWC system. The equipment was ordered in December 2021, delivered in mid-March 2022, and setup and operator training were completed in late March 2022. During March-May 2022, we conducted several un-replicated demonstrations in almond and other orchard crops and evaluated weed control in several bare ground sites with typical weeds for the region and time of year. Naturally occurring weed communities in the California locations included Italian ryegrass, California burclover, hairy fleabane, field bindweed, prostrate and redroot pigweed, common lambsquarters, and common purslane. Additional experiments and demonstrations were not conducted during summer because of poor weed growth under drought conditions and due to concerns of fire safety related to arcing from the EWC unit. Research in California will resume with fall weather and seasonal weed growth. Three trials were conducted at Cornell AgriTech to evaluate the impacts of travel speed, generator setting, and aboveground weed community on weed control, soil microbial respiration, soil microarthropod numbers, and soil weed seedbank germination. Studies are ongoing. These trials will serve as a basis for replicated studies to develop site- and weed-specific recommendations for electric weed control. Objective 2: Determine the impacts of electric weed control on weed populations, crop vigor and productivity, and soil health in-crop. OSU: We have ordered all plant and supply materials and met with our local organic certifier to ensure we meet all requirements. Crop planting is expected to start in Fall, 2022, as proposed in the project timeline. UC Davis: During this performance period, UC Davis activities have primarily been related to experimental design and coordinating supplies and planting materials. An organic blueberry planting will be established for the research during late fall or early winter 2022. Research related to EWC efficacy and blueberry crop safety will continue for the remainder of the grant period. Cornell AgriTech: The Cornell group will install this experiment in an existing organic blueberry block at their research farm. Objective 3: Perform cost and profitability analyses of electric weed control in bushberry and orchard crops. None Objective 4: Extend results to stakeholders and describe changes in grower knowledge about and interest in electric weed control. UC Davis: California stakeholders have been introduced to the project concept in cooperative extension meetings and small group meeting with commodity group leadership. Specifically, the EWC project was introduced in presentations at the annual Almond Conference (Sacramento, CA) on 12/3/2021 and the Walnut Research Conference (Bodega Bay, CA) on 1/27/2022. UC Davis PI Hanson and UC Davis grad student Zhen met with representatives from the California Blueberry Commission on 4/15/22 and 6/21/22 and with leadership of the Almond Board of California on 6/14/22. **Publications**

↑ Return to Index

Anaerobic Soil Disinfestation for Enhancing and Advancing the Sustainability of Organic Specialty Crop Production Systems (asd-easy Organic)

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Project No.	PENW-2021-02963
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Performing Institution	PENNSYLVANIA STATE UNIVERSITY, 408 Old Main, UNIVERSITY PARK, PENNSYLVANIA 16802-1505

NON-TECHNICAL SUMMARY

Soilborne pests and pathogens are among the major factors limiting yield in organic specialty crop systems. In these systems, effective integrated strategies are needed to preserve soil health and enhance the sustainability of organic horticulture. Anaerobic Soil Disinfestation (ASD) is an emerging biologically-based technology that promotes the simultaneous control of plant pathogens, plant parasitic nematodes, and weeds. The long-term goal of the present multiregional integrated research and extension project is to contribute to the long-term profitability and sustainability of organic specialty crop production systems by optimizing and integrating ASD as a viable biological technology for the simultaneous management of soilborne pests and pathogens and promoting and supporting soil health for the long-term. Coordinated research and on-farm trials will be conducted to optimize and integrate ASD into organic vegetable and strawberry cropping systems and assess the impact on soil health and the efficacy of ASD in managing key soilborne pests and pathogens in Florida and Pennsylvania, two states representative of the U.S. Northeast and Southeast region. Science-based knowledge developed throughout the project on ASD will be disseminated through local and regional outreach activities (on-farm trials and demonstrations, farmer focus groups, inservice training, workshops and meetings), and the national level eOrganic web platform (project webpage, project news, and updates, webinars, videos, English and Spanish fact sheets and manual), which combined, will contribute to transfer the ASD technology and relative application practices to organic growers and promote its adoption for the sustainable management of soilborne pests and pathogens affecting organic specialty crop systems.

OBJECTIVES

The long-term goal of the present multiregional integrated research and extension project is to contribute to the profitability and sustainability of organic specialty crop production systems by optimizing and integrating Anaerobic Soil Disinfestation (ASD) as a viable biological technology for the simultaneous management of soilborne pests and pathogens and preserving soil health for the long-term. Specific objectives of the projectare:1) Optimize and evaluate opportunities for integrating ASD in organic specialty crop systems as a

biological method to enhance soil health across the U.S. Northeast and Southeast region.2) Assess the short- and long-term impact of ASD on soil ecology and microbiome dynamics in organic specialty crop systems examining any consequent/interacting effect on nutrient dynamics, soilborne pests and pathogens, and overall soil health.3) Assess the efficacy of ASD as a system-based integrated management tool to address soilborne plant pathogens, plant-parasitic nematodes, and weeds affecting organic specialty crop systems in the U.S. Northeast and Southeast.4) Conduct advanced on-farm evaluations of ASD in different organic specialty crop systems to involve organic growers in the optimization of ASD and transfer the method to certified organic farmers operating within the U.S. Northeast and Southeast region.5) Evaluate the economic viability and identify barriers to adoption and integration of ASD in organic specialty crop systems in small- and medium- or large-size organic farms across the U.S. Northeast and Southeast region.6) Conduct a range of outreach activities employing multiple extension delivery methods to transfer science-based knowledge on ASD and promote its adoption for the management of soilborne pests and pathogens and of soil health in organic specialty crop systems at regional and national level.

APPROACH

Coordinated research and on-farm trials will be conducted to optimize and integrate ASD into organic vegetable and strawberry cropping systems and assess the impact on soil health and the efficacy of ASD in managing key soilborne pests and pathogens in two states representative of the U.S. Northeast and Southeast region. For the on-station \"mother\" research trials, treatments will be arranged according to a completely randomized block design with four replications. After the application of ASD treatments, soil oxidation-reduction potential sensors will be installed in each plot to monitor the soil redox potential (Eh) during the ASD treatment for 21-28 days. Soil temperature and moisture sensors will be installed in at least two replications. Data collected through data loggers will be monitored continuously and processed weekly to monitor soil Eh, temperature, and moisture. Soil Eh data will be used to calculate the cumulative Eh (ΣEh). Crops will be managed following local practices and certified organic standards. Visual assessments, soil sampling, and biometric assessments will be conducted at defined time intervals (every 30-45 days depending on the crop cycle) to evaluate any treatment effect on the crop, soil nutrient dynamics, and soil microbiome. Plant samples will be measured to determine the fresh and dry weight, dry tissue samples will be analyzed for their nutrient content and at harvest, produce will be analyzed for the quality profile measuring dry matter, total soluble solids (Brix), titratable acidity, and other quality parameters. In the case of fresh-market tomatoes at harvest fruit will be harvested based on color development from 10 representative plants per plot and fruit will be sorted by size category (extra-large, large, medium) and divided into marketable and unmarketable to determine different yield components and assess any effect in terms of earliness. Harvest dates and yield components will be recorded and used for the economic analysis. The same approach and methodology will be used consistently across all the coordinated \"mother\" research trials. All data will be subject to statistical analysis using SAS or R. On-farm demonstration and side-by-side testing of ASD in comparison with standard soil management practices will be conducted with selected cooperators in certified organic specialty crop systems (including vegetable and strawberry crops grown in open fields or protected environment) in both states. Science-based knowledge developed throughout the project on ASD will be disseminated by employing multiple extension delivery methods including i) local and regional outreach activities (on-farm research and demonstrations, farmer focus groups, in-person meetings, in-service training for extension educators, printed fact sheets, and a manual, workshops and presentations at local and regional grower meetings), and ii) national level outreach activities conducted through the eOrganic web platform (project webpage, project news and updates, webinars, videos, multilingual (English and Spanish) digital fact sheets and digital and printed manual), which combined, will contribute to transfer the ASD technology and practice to organic growers and promote its adoption for the sustainable management of soilborne pests and pathogens affecting organic specialty crop systems. Progress 09/01/23 to 08/31/24 Outputs Target Audience:The target audience reached through the project during the reporting period included organic vegetable and strawberry growers, producers transitioning to organic production, conventional growers who are interested in organic/sustainable production or biological management approaches for soilborne pest control and soil health improvement, extension agents and other agricultural service providers, educators, researchers, master gardeners, industry stakeholders and grower\'s associations, and the larger public. Changes/Problems:Given the challenges encountered at the Balm site during the 2022-23 season, we decided to repeat the ASD carbon and nitrogen application rates study in Citra, FL in the 2023-24 season in order to collect sufficient data to select top performing ASD treatments for follow-up strawberry cultivar assessment. A no-cost extension will be needed to accommodate this change of field research timeline. During this reporting period Thomas Ford, a Penn State Extension educator member of the PSU team, passed in December 2023, and Kate Rotindo an Extension Agen member of the Florida team left UF-IFAS, moreover two postdocs and a research tech left the project to move to new positions/roles. The tasks of the Extension educators are covered by other team members, while we are currently recruiting two new postdocs and a research tech to join us to help successfully complete the project. For

the next reporting period we can anticipate that hurricanes Helene (September 2024) and Milton (October 2024) caused significant damage to the GCREC farm; luckily, the newly installed ASD trial seemed to have held up relatively well, so we are continuing this trial. What opportunities for training and professional development has the project provided?During this reporting period, the project engaged 5 postdocs, 11 graduate students and 18 undergraduate students, 2 visiting research scholars, and 2 junior extension educators. The project also continued to engage 9 technical staff. Given the inter-disciplinary nature of the project trainees worked mostly as part of interdisciplinary teams within the same institution or across institution. Trainees participated in lab meetings aimed to plan activities and had the chance to learn about various aspects of the project in each laboratory group. Graduate students had the opportunity to mentor undergraduate students and present the results of the project on several occasions including academic and Extension meetings, on-farm demonstrations and visits. Trainees working in each lab had the opportunity to gain at least some of the following activities/skills: i) planning and designing experimental protocols, ii) implementing the ASD treatment, iii) setting-up and deploying data-loggers and relative soil sensors used to monitor soil temperature, soil redox potential and soil moisture, iv) collect soil samples in the field and process those to determine soil pH, EC, and mineral content, and DNA extractions in the laboratory, and troubleshooting issues in the laboratory, v) conduct biometric assessments on cover crops and tomato/strawberry plant samples and process the samples for the analysis of the mineral profile, vi) scout and manage a tomato/strawberry crop, vii) harvest and process tomato/strawberry fruit samples for yield and fruit quality assessment, viii) collect and analyze data, ix) recognize weeds and estimate weed pressure, x) extract nematodes from soil and measure the level of infestation, xi) inoculate/isolate soilborne pest and pathogens and evaluate ASD efficacy in their suppression, xii) understand the enterprise budget, develop the budget template, collect the data, and conduct the economic cost and benefit analysis, xiii) work independently and collaboratively in an interdisciplinary team, xiv) present the results at professional conferences, grower\'s meetings, to the larger public during outreach activities. Two postdoc researchers working with us since the beginning of this project landed in permanent positions (a postdoc took a faculty position in another university, while the second became research associate within the same institution) and we believe all the opportunities offered by this transdisciplinary, multi-institutional project prepared them very well professionally. Also, two biological scientists and some of the undergraduate students working on the project got new jobs in the industry after gaining deeper understanding of ASD application and organic crop production systems. How have the results been disseminated to communities of interest?The results of our research activities were disseminated to communities of interest through various Extension and outreach activities targeting different groups. In PA we had the opportunity to present and share information on ASD in occasion of: 1) Horse Progress Days (https://horseprogressdays.com/) an event attended by Amish and Mennonite communities gathering from across the US and other countries. Each day of the event we had the opportunity to present and demonstrate ASD, providing a printed factsheet with instructions on how to apply ASD. The presentations were attended by Amish and Mennonite growers and two of the attendees reached out to us later requesting assistance for the application of ASD on their farm. 2) Penn State\'s Ag Progress Days (https://agsci.psu.edu/apd), an annual event held in August in central Pennsylvania, held at our research station. Each of the three days of this event, we offered a 1-hour tour of our research site. For the three tours, there were 53 participants, including growers, agricultural professionals, master gardeners, and community members. In the open field, participants observed visual differences between tomatoes grown after a crimson clover cover crop and those grown after triticale. Participants asked questions about the ASD treatment and about cover crops. In FL on January 23, 2024, we hosted a field day at the UF/IFAS PSREU in Citra, FL to present some results from the organic strawberry ASD research trials and discuss the implementation of ASD in an organic strawberry production system. At the regional level, presentations were offered at grower meetings such as the 2023 Mid-Atlantic \"Virtual\" Vegetable Worker Conference, the 2024 Long Island Ag Forum (Riverhead, NY), the 2024 Mid-Atlantic Fruit and Vegetable Conventions in Hershey, PA (2 talks), the 2024 Florida State Horticultural Society Annual Conference (Orlando, FL), the Nematology Committee Annual Meeting (Davie, FL), and the 42nd Annual Strawberry Agritech Conference (Plant City, FL). Results of the projects were shared also through several one-on-one calls and interactions with growers. At the national level, two public webinars were conducted through the eOrganic platform in February and March 2024 and the results of the project were shared through oral presentations and seminars at the 2024 Annual meeting of the Society of Nematologists (Park City, Utah), at the University of California, Davis (seminar in the Department of Entomology and Nematology), at the University of Florida (seminars in the Department of Entomology and Nematology), at Penn State (through guest lectures and poster presentations) and the One Health Microbiome Symposium, held at University Park, PA. At the international level, results of the project were presented at the IV International Symposium on Organic Greenhouse Horticulture held in Cancun, Mexico; the Methyl Bromide Alternatives Outreach Conference in San Diego, CA; the 3rd Biocontrol Conference in Bari, Italy; the International Society of Microbial Ecology, in Cape Town, South Africa; the Association for International Agricultural and Extension Education Annual Conference, held in Orlando, FL; the 53rd Organization of Nematologists of Tropical America Annual meeting held in Cairo, Egypt. What do you plan to do during the next reporting period to accomplish the goals?In PA for Objective 1a.1

we will complete the analysis of the soil KCl extracts for NH4-N and NO3-N for the Year 3 experiment. With the data from the first two years of this experiment, we will submit a manuscript on how cover crops and organic amendments affect soil microbiome and a second manuscript on soil fertility following a spring ASD treatment in the open field in PA. Following the tomato harvest in the year 3 open field site, a cereal rye cover crop will be planted. We will also repeat this experiment for a fourth year, returning to site of the Year 2 experiment after planting cereal rye and soybeans in all plots during Year 3. We will use the same plot layout as year 2 (planting cover crops in the same locations) to maintain the legacy of the treatments and follow the same schedule and protocol for soil sampling, planting, and biometric assessments of the cover crops and tomatoes. For Objective 2, total genomic DNA will be extracted from collected soil samples for bacterial 16S rRNA and fungal ITS gene amplicon sequencing, which will allow us to assess the impact of ASD on soil bacterial and fungal dynamics, as well as microbial community functions in our field trial. This will provide insights into the long-term effects of ASD on soil microbial communities and enable us to identify the ideal carbon sources for ASD based on their long-term impact on tomato crop performance. We aim to publish the findings from the 2023-2024 tomato open-field experiment on the soil microbiome in a reputable scientific journal. For Objective 1a.2 we plan to complete the summer cover crop study planting lettuce and a second crop in the high tunnel to evaluate the impact of soil treatment on nutrient dynamics, crop yield and quality. For Objective 3, we plan to complete the bioassay on soil collected from on-farm demonstration trials pre- and post-ASD and aim to publish the results of different experiments. In FL for the next reporting period, we plan to compare performance of different (6) strawberry cultivars in selected ASD treatments under organic production at two locations in Florida (Citra and Balm, FL). Sunn hemp has been planted at both on-station sites to prepare the fields for the 2024-25 research trials. A double crop (squash) will be planted following strawberry. For Objective 4, 5, and 6, we plan to conduct more on-farm demonstrations, complete the economic analysis, and conduct additional Extension and outreach activities. We also plan to collect more field experiment data to repeat the economic analysis and draw more robust conclusions. The UF and PSU team will work to finalize the instruments of a grower survey to understand growers\' attitudes toward using ASD on their farms. Research and extension manuscripts will be prepared and submitted for publication and project findings will be disseminated through professional conferences and other outreach venues. Impacts What was accomplished under these goals? Coordinated trials were conducted in Pennsylvania (PA) and Florida (FL) in organic certified open field and high tunnel vegetable and strawberry production systems. Research trials and on-farm demonstrations contributed to developing new knowledge on anaerobic soil disinfestation (ASD) and the impact of alternative organic amendments and application strategies on the efficacy of the ASD treatment and its impact on soilborne pests and pathogens, soil microbiome, soil nutrient dynamics, crop growth and yield and quality performance. Although some research activities are still ongoing our interdisciplinary team is disseminating the knowledge developed among organic growers and industry stakeholders and is contributing to training a number of graduate and undergraduate students and postdoctoral researchers and Extension educators. The project is contributing to integrate ASD as a sustainable soil management technology in organic vegetable and strawberry production systems and we see a growing interest toward the application of ASD. Objective 1a.1 experiment in PA: We completed Year 2 of this experiment with final biometric assessment of the tomatoes and soil sampling at the end of September 2023. In October, we planted cereal rye in all plots, followed by soybeans (as a cover crop) planted in July 2024. Consistent with Year 1, results indicated the importance of the N content and C:N ratio of the cover crop biomass to the inorganic soil N levels during the ASD treatment and in the following growing season. In September 2023, we initiated Year 3 of this experiment using the same treatments and returning to the same site of Year 1, following cereal rye and soybeans during Year 2. Following the ASD treatment, tomatoes were planted in mid-June. Upon fruit ripening weekly harvests were conducted to assess soil treatment effects on yield components and fruit quality. For Objective 2, the team prepared soil extracts with deionized water to measure pH, EC, NH4-N and NO3-N. Objective 1b in PA we completed the high-tunnel experiment that began in Year 2 of the project, which used three organic amendments (soybean meal, molasses and wheat middlings) for an early fall ASD treatment, followed by a fall lettuce crop and then a spring tomato crop. We completed the analysis of soil pH, EC, and inorganic nitrogen for all samples collected. Objective 1a.2 in PA we started an experiment to test the potential of summer cover crops as a C source for the fall ASD application. Sunn Hemp and Sorghum-Sudangrass, were planted in monoculture and as a mixture of the two species along with a fallow control. The ASD treatment was implemented on August 23, 2024. For Objective 1 (FL), we repeated the organic strawberry ASD carbon and nitrogen inputs study in the 2023-2024 production season at PSREU in Citra, FL. The ASD treatments included 25 combinations of five C rates (blackstrap molasses at 0, 3.5, 6.9, 10.4, and 13.9 m3/ha) and five N rates (Everlizer 3-3-3, a heat-processed chicken litter product, at 0, 4.75, 9.5, 14.25, and 19 Mg/ha), arranged in a split plot design with 4 replications. Sunn hemp summer cover crop was planted in July and terminated in September 2023 to set up the 3-week ASD treatments on 09/19/2023. ORP and soil temperature sensors and lysimeters were installed together with weekly soil sampling and lysimeter sampling during the ASD treatment period to help monitor soil redox potential, temperature, and nitrate-nitrogen dynamics including nitrous oxide emissions. Overall, cumulative redox potential significantly increased with the increasing application rates of molasses. The

first season, higher molasses (10.4 and 13.9 m3/ha) and Everlizer (14.25 and 19 Mg/ha) application rates resulted in significantly lower number of nutsedges. However, inconsistent results were found in the second season. Plant aboveground biomass increased as the application rate of Everlizer increased in both seasons. The highest cumulative marketable strawberry yield in the first season was observed with molasses and Everlizer applied at 13.9 m³/ha and 9.5 Mg/ha, respectively, while 13.9 m³/ha of molasses and 14.25 Mg/ha of Everlizer was the top performer in the second season. No negative effects of ASD were observed in strawberry fruit quality attributes. During the same experiment for Objective 3, Embedded in each plot were two pathogen packets containing either Macrophomina phaseolina or Fusarium oxysporum spores to determine the effectiveness of the soil treatment on managing these soilborne pathogens. Soil and root samples were collected to quantify and separate different nematode feeding groups (bacterial, fungal and omnivores) and/ or major plant-parasitic nematode genera. The data indicated significant treatment effects on bacterivorous, fungivorous, omnivorous, and predatory nematodes. Plant-parasitic nematodes included Meloidogyne spp., Belonolaimus sp., Pratylenchus sp., Helicotylenchus sp., Trichodorus sp. and Xiphinema sp., but populations of these were low, and no treatment differences were noted. In fulfillment of Objective 3, in PA, ASD was implemented in a commercial high tunnel that had a history of dagger nematodes transmitting plant viruses. Soil samples were collected before and after the ASD process. Bioassay tomato plants (\'Moneymaker\') were directly seeded into the soil samples and grown for 8 weeks. Three of the twenty plants grown in pre-ASD treated soil developed plant virus symptoms. One of these symptomatic plants tested positive for tomato ringspot virus (ToRSV) using an ELISA immunoassay strip. None of the plants grown in the post-ASD treated soil developed viral symptoms and ELISA testing came back as negative for these plants. Subsamples of each soil sample were also used to determine nematode counts and for the molecular detection of C. coccodes. Dagger nematodes were detected in all blocks pre-ASD (range 2 to 104 nematodes per 100c of soil) but in the post-ASD treated blocks only 1 dagger nematode was extracted from all the samples. C. coccodes detection decreased post-ASD from being detected 75% of the block before and only 6% of the blocks following ASD treatment (n=16). For Objective 4, on-farm ASD demonstrations were conducted in PA (3) and in FL (4) as described above in the \"Other products\" section on farms focused on vegetable and small fruit crops and characterized by the presence of different soilborne pest and pathogen issues. For Objective 5 production cost data based on the organic strawberry and the tomato ASD field trials were collected along with the price data from government agencies such as USDA and other online sources. For the strawberry study, results showed that despite the higher labor costs, the ASD treatments led to higher gross returns than the control (zero carbon and nitrogen input) in both growing seasons. The net return of ASD treatments varied with the carbon and nitrogen application rates and the season. We also gathered information on farmers\' farm-related data and their familiarity with ASD at the field day conducted in Citra, FL. We explored perceived opportunities for ASD adoption and potential challenges that farmers may encounter. Most respondents recognized the potential benefits of implementing ASD, such as improved yield, enhanced soil fertility, and enhanced control of soilborne diseases. However, they also indicated a lack of knowledge and training as the primary challenge, followed by the increased material cost. Based on this preliminary survey, FL and PA researchers worked together to develop a grower survey to understand the barriers and motivations for specialty crop growers to adopt ASD on their farms. For Objective 6 a series of Extension and Outreach activities were conducted in PA, FL and at national and international level as described in the \"Other products\" section. Publications Type: Conference Papers and Presentations Status: Accepted Year Published: 2025 Citation: Di Gioia F., Balaguer R., Pierre F., Morrison B., Ono-Raphel J., Passerini L., Vecchia L., Demchak K., Roman C., Schmidt C., Gugino B., Elkner T., Hong J.C., Dini-Andreote F., Rosskopf E. Optimizing the Application of Anaerobic Soil Disinfestation to High Tunnel Vegetable Production Systems in the U.S. Mid-Atlantic Region. X Intern. Symposium on Soil & Substrate Disinfestation. In press \Accepted May 9, 2024\. Type: Conference Papers and Presentations Status: Accepted Year Published: 2024 Citation: Di Gioia F. Hong J.C., Desaeger J., Arrington K., Dini-Andreote F., Zhao X., Schmidt C., Gao Z., Balaguer R., Ono-Raphel J., Morrison B., Moreira Calix D., Xu N., Fronk L., Ford T., Elkner T., Goodiel Y., Rotindo K., Formiga A., Demchak K., Gugino B., Kaye J., Rosskopf E. Advancing Organic Amendment-based Soil Management Approaches: A Paradigm Shift from Soil Disinfestation to Nourishing Soil Health. X Intern. Symposium on Soil & Substrate Disinfestation. In press \Accepted May 9, 2024\. Type: Conference Papers and Presentations Status: Submitted Year Published: 2024 Citation: Di Gioia, F., Ono-Raphel, J., Arrington, K., Balaguer, R., Dini Andreote, F., Kaye, J., & Rosskopf, E. \"Leveraging By-Products of the Agri-Food Industry for the Application of Anaerobic Soil Disinfestation in Organic High Tunnel Vegetable Production.\" IV International Symposium on Organic Greenhouse Horticulture. Cancun, Mexico, October 22-27, 2023 \Submitted January 8, 2024\. Progress 09/01/22 to 08/31/23 Outputs Target Audience:The target audience reached through the project during the reporting period included organic vegetable and strawberry growers, transitional organic producers, conventional growers who are interested in organic/sustainable production or biological management approaches for soilborne pest control and soil health improvement, extension agents and other agricultural service providers, educators, researchers, master gardeners, industry stakeholders, and the larger public. Changes/Problems:In PA, for Objective 1a, in the open-field experiment, tomatoes were planted in early June. Variability in seedling size combined with high temperatures led to poor survival of the transplants.

Tomatoes were replanted approximately 4 weeks later, which was a late planting date for the area, and resulted in a shorter harvesting season. We planted summer cover crops (Sunn Hemp and Sorghum-Sudangrass) in early July in the uncovered high tunnel with the goal of starting an ASD treatment in late summer followed by a fall vegetable crop. There were several issues with the summer cover crops. First, we made a planting mistake by not seeding the full uncovered high tunnel area, which would have resulted in smaller plot sizes. Second, during planting a belt broke on the cone seeder causing an uneven distribution of seeds. (We attempted to fill in bare spots by replanting by hand.) Finally, the cover crops grew poorly, possibly due to the amount of rain; standing water was observed in low spots in the site. We decided to discontinue the experiment because we expected that there would not be enough cover crop biomass to produce a successful ASD treatment. The summer cover crops were mowed, and we planted a mixture of cover crops in the area (crimson clover, triticale and canola). Objective 1b: Cabbages were planted in late August 2022 in the high tunnel, following an ASD treatment with raised beds that had received organic amendments (soybean meal, wheat middlings, and molasses, alone or in combination). Shortly after planting, approximately one-third of the cabbage plants were damaged (chewed by wild animals). Although we replanted, installed a fence, and sprayed an organic repellent, more plants were damaged. Ultimately, we decided to discontinue the experiment due to an insufficient number of healthy plants to assess the impact of the organic amendments and ASD treatment on the following cabbage plants. We decided to move the high tunnel and repeat the experiment at the opposite end of the rails. We reapplied the same organic amendment treatments and started a new ASD treatment which ran for 3 weeks. At the end of September, we planted lettuce instead of cabbage due to the shorter time remaining in the growing season. The weather conditions and the ability to manage conditions within the high tunnel provided us with approximately 10 weeks for the lettuce crop, which was harvested in mid-December. In FL Hurricane Ian which hit the area of Balm late September 2022 and had a negative effect on the set up of both ASD × Solarization and the C and N input field trial. While cover crops were incorporated on September 16th, due to the hurricane, ASD treatments could not be applied until October 11th and 12th. Moreover, disease, insect and weed pressure was very high which negatively impacted strawberry growth and yield in the 2022-23. Weed pressure, particularly that of nutsedge (Cyperus spp.), which has the ability to pierce through the plastic, has become one of the major problems in our organic field. Therefore, we decided to conduct the experiment again at the Citra location in the 2023-2024 strawberry production season. Consequently, the strawberry cultivar evaluation under ASD treatment in FL has been delayed and will be conducted later (possibly in the 2024-2025 season). What opportunities for training and professional development has the project provided?During this reporting period, the project engaged 4 postdocs, 8 graduate students and 9 undergraduate students, 1 visiting research scholar, and 2 junior extension educators. The project also continued to engage 9 technical staff. Graduate and undergraduate students worked together under the supervision of one or more faculty and given the inter-disciplinary nature of the project often worked as part of interdisciplinary teams within the same institution or across institution. Trainees participated in weekly lab meetings aimed to plan activities and had the chance to learn about different aspects of the project in each laboratory group. Graduate students had the opportunity to mentor undergraduate students and present the results of the project on several occasions including academic and Extension meetings, on-farm demonstrations and visits, and conducted also teaching activities. Training opportunities offered to gain the following activities/skills: i) planning and designing experimental protocols, ii) implementing the ASD treatment, iii) setting-up and deploying data-loggers and relative soil sensors used to monitor soil temperature, soil redox potential and soil moisture, iv) collect soil samples in the field and process those to determine soil pH, EC, and mineral content, and DNA extractions in the laboratory, v) conduct biometric assessments on cover crops and tomato/strawberry plant samples and process the samples for the analysis of the mineral profile, vi) scout and manage a tomato/strawberry crop, vii) harvest and process tomato/strawberry fruit samples for yield and fruit quality assessment, viii) collect and analyze data, ix) recognize weeds and estimate weed pressure, x) extract nematodes from soil and measure the level of infestation, xi) inoculate/isolate soilborne pest and pathogens and evaluate ASD efficacy in their suppression, xii) understand the enterprise budget, develop the budget template, collect the data, and conduct the economic cost and benefit analysis, xiii) work in an interdisciplinary team, xiv) present the results at professional conferences, grower\'s meetings, to the larger public during outreach activities. How have the results been disseminated to communities of interest?Tours of our research plots were organized during Penn State\'s Ag Progress Days, an annual event held in August in central Pennsylvania, a short bus ride from our research station. Each of the three days of this event, we offered a 1-hour tour of our research site. For the three tours, there were approximately 70 participants, including growers, agricultural professionals, master gardeners, and community members. In the open field, participants observed visual differences between tomatoes grown after a crimson clover cover crop and those grown after triticale. Also notable was the difference in size between the tomatoes grown in the open field planted in mid-June and those planted in the high tunnel in late April. Participants asked many questions about the ASD treatment and high tunnel vegetable production. In FL a talk and a research trial visit were organized as part of a field day on organic vegetable production research at UF/IFAS PSREU in Citra on December 8, 2022 to introduce ASD application in organic strawberry production systems. At regional level, presentations were offered at grower meetings such as the Mid-Atlantic Fruit and

Vegetable Conventions (Hershey, PA), Long Island Ag Forum (NY), Ephrata Agway Grower Meeting (PA), the Florida Strawberry Growers Association (FSGA) annual growers field day (Dover, FL) and the 41st Annual Strawberry Agritech Conference (Plant City, FL). Results of the projects were shared also through one-on-one interactions with growers. At the national level, the first public webinar was conducted through eOrganic in February 2023 and results of the project were shared through several oral presentations at the 2023 American Society for Horticultural Science conference in Orlando, FL. At the international level, results of the project were presented at the X International Symposium on Soil and Substrate Disinfestation conducted in Almeria, Spain and at Zamorano University in Honduras. What do you plan to do during the next reporting period to accomplish the goals?Objective 1a: In PA we will complete the analysis of the soil KCl extracts for NH4-N and NO3-N to assess the soil nitrogen dynamics during the ASD treatment and the following tomato crop. With two years of data for this experiment, we will begin working on publishing the results. Following the tomato harvest in the year 2 open field site, a cereal rye cover crop will be planted. We will also repeat this experiment for a third year. The first two years of this experiment were run in adjacent sites with the tomatoes still growing in the year 1 site at the time of planting cover crops for the year 2 site. For the third year of the experiment, we will return to the year 1 site after a year of cover crops: cereal rye (fall through spring) and soybeans (summer) grown across all plots. We will use the same plot layout as year 1 (planting cover crops in the same locations) to maintain the legacy of the treatments. For the third year of this experiment, we will follow the same protocol for soil sampling, planting, and biometric assessments of the cover crops and tomatoes and this will allow us to evaluate the long-term effect of ASD. For Objective 1b we plan to continue the data collection in the high tunnel study and plan to repeat the summer cover crop study that failed during this reporting period. For all the trials conducted in PA we plan to run a partial budget analysis and evaluate the economic viability of tested treatments. For Objective 2a, we aim to publish the findings from the 2021-2022 tomato open-field experiment in a research article. Additionally, we will continue to investigate other aspects of the soil microbiome during ASD, including shifts un fungal communities and microbial functions (via metagenomics). In FL, for the next reporting period, we plan to repeat the field experiment examining various levels of C and N inputs for ASD application in organic strawberry production at the Citra location. The Ag Economy team will continue working with researchers in horticulture sciences to refine the production budget template, trying to make a protocol for economic data collection based on biological field trials. We will also start inputting data based on the field experiment conducted in Florida. We plan to collect more data based on the second-year experiment to repeat the economic analysis to draw more robust conclusions. Two additional webinars are being planned for the winter of 2023-24. The project website will be updated with additional photos, publications, videos, announcements, archived webinars and other outreach products. We also plan to write research and extension articles, conduct more on-farm trials and demonstrations, conduct a survey to assess growers perception of ASD and identify potential obstacles to adoption, and organize/participate in field days/workshops to disseminate and transfer project findings. Impacts What was accomplished under these goals? For Obj.1a experiment in PA (cover crops and ASD in the open field): We completed year 1 of this experiment with final biometric assessment of the tomatoes and soil sampling at the end of September 2022. In October, we planted cereal rye in all plots, followed by soybeans (as a cover crop) planted in July. For Obj.2b, we completed the analysis of NH4-N and NO3-N for the soil extracts prepared with 2M KCl. Results indicated the importance of the nitrogen content and C:N ratio of the cover crop biomass to the inorganic soil N levels during the ASD treatment and in the following growing season. For Obj.2a total soil DNA was extracted from soil samples collected during the 2021-2022 growing season to perform bacterial 16S rRNA gene amplicon sequencing. Sequencing data was analyzed to assess the impact of ASD on the soil ecology and microbiome dynamics in the field experiment. In mid-September 2022, we initiated a second year of this experiment using the same cover crop species (crimson clover, triticale and a mixture of the two) along with a fallow control. We repeated the methods used inyear 1.Dry weather during the last two weeks of May caused anaerobicity in the field to decline, so tomatoes were planted one week earlier than in year 1 (June 1), although they had to be replanted approximately 3 weeks later (see changes/problems). Starting when the tomatoes were replanted, soil samples were collected approximately monthly corresponding with biometric assessments of the tomatoes. All soil samples during the ASD treatment and under the tomatoes were subdivided in the field in preparation for microbial and chemical analyses. For Obj.2b, weprepared soil extracts with 2M KCl, which will be analyzed for NH4-N and NO3-N. A biometric assessment was conducted to evaluate treatment impact on plant growth. Tomato fruits were harvested four times measuring yield components and fruit quality. In July, we initiated an experiment with summer cover crops as part of Obj.1a.2. We selected one legume species (Sunn Hemp) and one grass species (Sorghum-Sudangrass), which were planted in monoculture and a mixture of the two species along with a fallow control. The species were expected to provide a range of C:N ratios, similar to the winter cover crops in Obj.1.a.1. We planned to terminate the cover crops in late summer, followed by an early fall ASD treatment and then a fall lettuce crop. However, there were some issues with the planting and growth of the cover crops (see changes and problems), so we decided to discontinue the experiment. Obj.1b in PA (organic amendments in the high tunnel): At the end of year 1, we initiated this experiment in the high tunnel using three organic amendments (soybean meal, molasses and wheat middlings). Each amendment was applied as follows:

soybean meal (full and half rate), molasses (full rate), wheat middlings (full rate), soybean meal and molasses (half rate each), soybean meal and wheat middlings (half rate each) along with two fallow controls (with and without water), for a total of eight treatments replicated four times. The design provided a wide range of C:N ratios, since in the first year of Obj.1a.1, this was found to be an important factor in ASD efficacy and N availability to the following vegetable crop. Unfortunately, there were some issues with the following cabbage crop (see changes and problems). We discontinued the experiment, moved the high tunnel, and repeated the experiment in the new area beginning in mid-September 2022. We used the same soil sampling protocol described above to assess the microbial and nutrient dynamics during and following the ASD treatment. Lettuce was planted approximately three weeks after the ASD treatment. Soil sampling and biometric assessments of the lettuce were done in mid-November and at harvest. In late April 2023, we continued the experiment by planting tomatoes in the high tunnel in the same beds as the lettuce, with no additional fertilizer added. This 2nd phase of the experiment will investigate the long-term effects of the ASD treatment. Using the same methods, soils were sampled monthly through the spring and summer, corresponding with biometric assessments of the tomatoes. In fulfillment of Obj.3, in PA a series of three greenhouse experiments were conducted to evaluate the use of different carbon sources (liquid molasses with either composted poultry litter (CPL), wheat middlings, and/or dry molasses) to conduct anaerobic soil disinfestation (ASD) for the management of black dot root rot (Colletrotricum coccodes), timber rot (Sclerotinia sclerotiorum), corky root rot (Pseudopyrenochaeta lycopersici). Microcosms were used to facilitate exposure and retrieval of a quantified pathogen population to the ASD process. For the first experiment, cell culture inserts were used to contain three small filter paper disks colonized by a quantified number of C. coccodes microsclerotia. The subsequent two experiments used small pouches made from the 0.5 or 0.2-micron filters from two mushroom grow bags that were heat sealed shut. A known quantity of pathogen was placed in each microcosm. In the latter two experiments, one microcosm of each of the three fungal pathogens was placed in each pot. Anaerobicity was measured using both IRIS tubes and Campbell Scientific ORP sensors. Each pot was sealed with a sheet of totally impermeable film plastic. Hobo pendent temperature sensors were also placed in each pot for the duration of the experiment. Each experiment was run for three or four weeks and then data regarding anaerobicity and pathogen survivability were collected.? For Obj.1c in FL, the field research trial on C (molasses) and N (Everlizer - poultry litter based organic fertilizer) application rates in ASD for organic strawberry production was conducted on certified organic land at the UF/IFAS PSREU in Citra and the GCREC in Balm, respectively. A laboratory incubation study was also conducted from 09/15/2022 to 12/09/2022 to assess N mineralization dynamics. During the sunn hemp growing period, data collected included sunn hemp plant height, fresh and dry aboveground biomass (leaf and stems, separately), C and N contents. During ASD, we collected ORP data, soil temperature data, weekly NO3-N in leachate samples, N2O gas data, weekly soil NH4-N and NO3-N, pH, EC, and macro- and micronutrients, weekly soil organic acid content and moisture, and pathogen data. During the strawberry production period we conducted plant biometric assessments, weed assessment, fruit yield and quality (pH, soluble solid content (SSC), titratable acidity (TA), SSC/TA ratio, total phenolic content, total antioxidant capacity). During the catch crop period, data collected included macro- and micronutrient contents of soil and plant samples and plant biometrics measurements. For Obj.5 in FL we collect the production cost data based on strawberry experiment trial and price data from government agencies such as USDA and other online sources. Based on the data, we conduct economic analysis of different ASD treatments in addition to the one without ASD implementation. A 3rdstrawberry field trial was initiated at the organic certified research farm of the GCREC in July 2022 and finalized in April 2023 to evaluate the effect of use of ASD combined or not with soil solarization (second repetition from previous year). A cover crop consisting of a mix between sorghum-sudangrass (Sorghum × drummondii) and cowpea (Vigna unguiculata) was planted on July 7th, 2022. The cover crop was flail mowed and incorporated mid-September 2022. The ASD × solarization trial was done on the same field as the first year, and the same procedure as in 2021-22 was followed. The same strawberry cultivars were planted on October 11, 2022. Evaluations included stand counts, and for Obj.3 weed counts (broadleaf vs. grasses) and nematode soil counts. Nematode samples have been extracted and counted and data are being analyzed. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Di Gioia, F., Balaguer, R.M., & Passerini, L. 2023. Soil Fertility Management Post Anaerobic Soil Disinfestation in a Tomato High Tunnel Production Systems. 2023. Mid-Atlantic Fruit and Vegetable Convention Proceedings. (13-14). Richfield, PA: Pennsylvania Vegetable Growers Association. Type: Conference Papers and Presentations Status: Submitted Year Published: 2023 Citation: Di Gioia F., Balaguer R., Pierre F., Morrison B., Ono-Raphel J., Passerini L., Vecchia L., Demchak K., Roman C., Schmidt C., Gugino B., Elkner T., Hong J.C., Dini-Andreote F., Rosskopf E. Optimizing the Application of Anaerobic Soil Disinfestation to High Tunnel Vegetable Production Systems in the U.S. Mid-Atlantic Region. X Intern. Symposium on Soil & Substrate Disinfestation \Submitted August 9, 2023\. Type: Conference Papers and Presentations Status: Submitted Year Published: 2023 Citation: Di Gioia F. Hong J.C., Desaeger J., Arrington K., Dini-Andreote F., Zhao X., Schmidt C., Gao Z., Balaguer R., Ono-Raphel J., Morrison B., Moreira Calix D., Xu N., Fronk L., Ford T., Elkner T., Goodiel Y., Rotindo K., Formiga A., Demchak K., Gugino B., Kaye J., Rosskopf E. Advancing Organic Amendment-based Soil Management Approaches: A Paradigm Shift from Soil Disinfestation

to Nourishing Soil Health. X Intern. Symposium on Soil & Substrate Disinfestation \Submitted August 10, 2023\. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:The target audience reached through the project during the reporting period included organic vegetable and strawberry growers, transitional organic producers, conventional growers who are interested in organic production or biological management approaches for soilborne pest control and soil health improvement, extension agents, and other agricultural service providers, educators, researchers, and industry stakeholders. Changes/Problems: In PA, for the Objective 1a experiment, we added a second control to the experimental design. Within the area where cover crops were planted, fallow plots receiving the ASD treatment served as our first control. These plots will allow us to understand how the cover crops and organic amendments changed the ASD treatment. We added an extra row of plots at the edge of the site (an area that had also been fallow) where raised beds were constructed, sensors and black plastic were placed, but no water was applied during the ASD treatment. These plots served as a second control by providing a baseline to compare to the fallow plots where water was applied, effectively separating the effects of the water application from the cover crops/organic amendments. In FL, due to unforeseen complications, Objective 1c experiments that were scheduled to start right at the beginning of the first year of the project at Citra and Wimauma, FL were initiated at the end of the first reporting period and will be completed by the second reporting period. Disease, insect, and weed pressure can be very high in Florida and is more difficult to manage in organic certified fields. This negatively impacted strawberry growth and yield in the 2021-22 season. For the 2022-23 season, we have some new OMRI-approved fungicides and insecticides available that we intend to use. What opportunities for training and professional development has the project provided?Extension activities are reported in the dissemination section. An important goal and productive outcome of this project have been training the next generation of scientists and professionals. During this reporting period, the project engaged 7 postdocs, 7 graduate students, and 8 undergraduate students. Moreover, the project engaged a minimum of 9 technical staff as they advanced their skills and expertise on Anaerobic Soil Disinfestation and its application in organic vegetable and strawberry crop systems. Students were engaged directly under the supervision of faculty or under teams of faculty (in the case of graduate student committees) and in some cases by faculty from multiple institutions. Trainees were trained in diverse disciplines consistent with the interdisciplinary nature of the project and worked in interdisciplinary teams. Trainees participated in weekly lab group planning meetings and had opportunities to learn about different aspects of the project in each laboratory group. Graduate students had the opportunity to mentor undergraduate students and started presenting project outcomes at meetings and were engaged in Extension and teaching activities. Training typically included the following activities/skills: i) planning and designing experimental protocols, ii) implementing the ASD treatment, iii) setting up and deploying data loggers and relative soil sensors used to monitor soil temperature, soil redox potential, and soil moisture, iv) collect soil samples in the field and process those to determine soil pH, EC, and mineral content, and DNA extractions in the laboratory, v) conduct biometric assessments on cover crops and tomato plant samples and process the samples for the analysis of the mineral profile, vi) scout and manage a tomato crop, vii) harvest and process tomato fruit samples for yield and fruit quality assessment, viii) collect and analyze data. How have the results been disseminated to communities of interest? Growers, Extension educators, and people who advise growers frequently ask questions about anaerobic soil disinfestation. Finding reliable research-based information can be challenging. During the reporting period, a website dedicated to the project was created within the eOrganic web platform (<https://eorganic.info/ASDEasyOrganic>). The website was updated with links to resources on anaerobic soil disinfestation and a photo gallery showing details of ASD applications. Results of the project and information on ASD have been disseminated to stakeholders through emails, phone and Zoom calls, or on-farm conversations initiated by growers and stakeholders;as well as through presentations at conferences and workshops. In PA two Extension talks were given at the 2022 Mid-Atlantic Fruit & Vegetable Convention, one in the Organic Vegetable session presented by F. Di Gioia and titled 'Anaerobic Soil Disinfestation (ASD) for Organic Specialty Crop Production Systems' (45 attendees) and the second in the High Tunnel session I presented by R. Balaguer and titled 'Evaluating Carbon Sources for ASD in High Tunnel Production in PA' (25 attendees). Moreover, a webinar targeting vegetable growers was conducted through Penn State Extension. The outcomes of the project and teaching concepts about Anaerobic Soil Disinfestation were presented in the following undergrad and graduate level courses at Penn State: AGECO 201: Introductory Agroecology, Plant 461: Emerging Issues in Plant Science, and Plant Biology 513. An online guest lecture was offered to a graduate student class at Washington State University. Preliminary results of the project were also presented at the 2022 American Society for Horticultural Sciences Annual Conference held in Chicago, IL, and at the 2022 Methyl Bromide Alternative Outreach Annual Conference held in Maitland, FL. In FL, two in-person presentations were conducted for Master Gardener instruction in Florida, one in St. Lucie County (9 participants) on March 15, 2022, and a second in Martin County (18 participants) on April 13, 2022. What do you plan to do during the next reporting period to accomplish the goals? During the next reporting period, we plan to complete the research activities initiated during the first reporting period and initiate new research trials and extension activities according to the project timeline. In more detail, the analysis of soil samples collected during the reporting period from field trials of Obj. 1a, 1b, 1c, and 1d will be completed for chemical, microbial, and

nutrient analyses (NH4-N, NO3-N, and labile P). Objective 1a experiment will be repeated at an adjacent site with the same cover crops and organic amendment. The Objective 1b experiment initiated in year 1 will be completed with biometric assessments and soil samples to compare the effectiveness of the organic amendments as carbon sources for a late-summer ASD treatment followed by a fall vegetable crop in a high tunnel. In PA we will initiate a new experiment to test summer cover crops before an ASD treatment followed by a fall vegetable crop. At the PSU horticulture research farm, the uncovered portion of the high tunnel is currently planted in the triticale-crimson clover mix, the treatment which generated the most biomass in year 1 of the Objective 1a experiment. This mixture will be mowed and incorporated into the soil in May, followed by a planting of summer cover crops, such as Sorghum sudangrass and Sunn hemp. One organic amendment will be selected (based on the results of the Objective 1b experiment from year 1) to apply to half of each cover crop plot before the ASD treatment. Following the ASD treatment, a fall vegetable crop will be planted under the high tunnel. In FL, during the next reporting period, the team will complete the field experiment examining various levels of nitrogen and carbon inputs for ASD application in organic strawberry production (Obj. 1c). This field study is ongoing in two locations, at the UF/IFAS Plant Science Research and Education Unit (PSREU) in Citra, FL and the UF/IFAS Gulf Coast Research and Education Center (GCREC) in Wimauma, FL. The ASD treatments initiated during the first reporting period consist of 25 combinations of five application rates of molasses and five application rates of organic N fertilizer. After the 21-day ASD treatment period, the 'Florida Brilliance' strawberry will be transplanted. A series of measurements will be conducted during the ASD treatment period to assess soil N status, anaerobicity, and nitrous oxide emission. Weed, disease, and nematode assessments will be performed throughout the strawberry production season. In addition to plant biomass and fruit yield components, basic fruit quality attributes will be measured. In connection with this study, a 12-week lab incubation study will be conducted to determine soil N mineralization dynamics of ASD treatments with different levels of N and C inputs. The field study conducted for Obj. 1d in the first reporting period at the UF/IFAS Gulf Coast Research and Education Center (GCREC) in Wimauma, FL, will be repeated on the same research plot, using the same treatments, to evaluate longer-term effects of the ASD treatment. For Objective 4, during the next reporting period, we plan to start on-farm demonstration trials both in PA and FL. For Objective 5a, during the first report period, a budget template has been developed by Gao's team in collaboration with researchers conducting field trials in FL and PA to coordinate the collection of data for economics analysis on ASD. During the next reporting period, following the budget template, ASD application costs and crop yield data and produce prices recorded will be used to conduct an economic analysis to determine the treatments that are most economically feasible. For Objective 6 we plan to continue updating the webpage and will conduct a series of Extension and outreach activities (including webinars, fact sheets, workshops, in-service training, field days, and videos) as planned in the project. **Impacts** What was accomplished under these goals? Regional coordinated trials were conducted in Pennsylvania (PA) and Florida (FL) in organic certified open field and high tunnel vegetable and strawberry production systems. These trials contributed to developing new knowledge on anaerobic soil disinfestation and the impact of alternative organic amendments and application strategies on the efficacy of the ASD treatment and its impact on soil nutrient dynamics, soil microbiome, and crop growth and yield performance. Although most of the research activities are still ongoing our interdisciplinary team started disseminating the knowledge developed among organic growers and industry stakeholders and is contributing to form a number of graduate and undergraduate students and postdoctoral researchers and Extension educators. The project is contributing to integrating ASD as a sustainable soil management technology in organic vegetable and strawberry production systems. In PA, Di Gioia, Kaye, and Dini-Andreote teams established two ASD experiments on organic certified land at the Penn State Horticulture Research Farm in Pennsylvania Furnace, PA. One experiment was established in the open field, the second in a high tunnel. For Objective 1a the first study cycle was completed. The study aimed to investigate the opportunity to integrate ASD with the use of cover crops in an organic tomato crop system. The ASD treatment was applied prior to tomatoes using cover crops as carbon sources by themselves or supplemented with an organic amendment (wheat middlings). Two winter-hardy cover crop species were planted in mid-September: crimson clover and triticale and a mixture of the two with a fallow control. Several biometric assessments over the cover crops were done, including stand counts, fall sampling for %C and %N, and NDVI readings to estimate nitrogen content (fall and spring). Cover crop biomass was sampled in May, just prior to mowing and incorporating cover crops. Plots were split into two sections and wheat middlings was added to half of the plot. The ASD treatment was established with raised beds constructed, a drip irrigation system established, soil temperature and redox potential (ORP) sensors placed and covered with black plastic, followed by 4 hours of drip irrigation. Soils were sampled at 1,4, 7, 14, 21, and 28 days after the initiation of the ASD treatment (Objective 2a and 2b). Soil samples were divided in the field to prepare for chemical, microbial and nutrient analyses. Soil subsamples from each experimental unit were processed for different analyses: soil water extracts (1:2 v:v) were used to measure variations in pH and electrical conductivity (EC). Processing included KCl extractions to prepare for NH4-N and NO3-N analyses, as well as air-dry soil samples, which were prepared for labile P analyses. Tomatoes were planted in June and biometric assessments were done in mid-July and mid-August, with soil samples collected on the same days. Soil subsamples collected for microbiome

analysis (Objective 2a) were stored at -80 C pending microbial analysis. Total soil DNA extraction was carried out using 0.5 g of initial material with the DNeasy PowerSoil Pro Kit (Qiagen). The quality and quantity of extracted DNA were checked using NanoDrop (Fisher Scientific). To target bacterial communities, samples were subjected to partial 16S rRNA gene amplification using the primer set 505F and 806R. The amplicons in each sample were subjected to high throughput sequencing on an Illumina Miseq platform (2×250 bp). The raw sequence data for this experiment are currently being analyzed. The study revealed the key role cover crops and their C:N ratio play in determining the efficacy of the ASD treatment and the impact on nutrient dynamics during and post-ASD, and on plant growth and yield. A second experiment was established to test the effect of several organic amendments as carbon sources for the application ASD prior to a fall cabbage crop grown within the moveable high tunnel (Objective 1b). Treatments tested included untreated control (with and without initial water) and wheat middlings, soybean meal, and molasses applied at two application rates. The ASD treatment was established in late July and soil samples were collected with the same methods and frequency as Objective 1a. Cabbage was planted in late August following the ASD treatment. In FL, Hong, Rosskopf, and Desaeger teams established a coordinated strawberry ASD field trial at the organic certified research farm of the Gulf Coast Research and Education Center (GCREC) of the University of Florida in September 2021 and finalized in May 2022. This field trial was a multifactorial experiment, which compared various amendments and two types of plastic mulches. Prior to the experiment, the field was seeded with a mixture of cowpea and sorghum-sudangrass was planted in early July. In correspondence with the ASD application, the cover crop mix was mowed and tilled into the soil. The following day false beds were created for half of the trial, while for the other half flat beds were created. A combination of molasses, or molasses, and pelletized composted poultry manure were incorporated into the soil. Moreover, some beds did not receive additional soil amendments besides the mulched cover crops. The false beds were covered with black total impermeable film (TIF) and the flat beds were covered with solarization plastic film. Comparison of the plastics was performed in block design, while comparison for amendments was performed in a randomized plot design. The soil was watered to field capacity. In each experimental unit were incorporated two different pathogen packets containing either *Fusarium oxysporum* sp. *fragariae* or *Macrophomina phaseolina*. The packets were collected after the three-week ASD treatment and platted to determine survivability of the plant pathogens. Soil conditions were monitored in each experimental plot using soil temperature and oxidation-reduction probes (Objective 1d). Soil samples were collected prior to adding the additional amendment and tarping of the soil, three weeks post-treatment, at first harvest, the last harvest, prior to planting a second crop, midseason, and harvest of the second crop. Soil samples were taken for nutrient content (Objective 2b), DNA extraction to observe the microbiome (Objective 2a), and to quantify parasitic and free-living nematodes (Objective 3b). Three weeks after application, solarization films were removed, raised beds were formed, and mulched with black TIF plastic strawberry plants were planted using two different varieties (Sweet Sensation and Florida Brilliance, one variety per row). The crop was monitored and rated every two weeks, evaluations included stand counts, plant vigor ratings (using a handheld GreenSeeker), weed counts, and nematode soil counts. Nematode samples have been extracted and counted and data are being analyzed. Plant-parasitic nematodes included lesion, sting- and root-knot nematodes, but populations were low throughout the season. Free-living nematodes were mostly bacterial and fungal-feeding nematodes. Strawberry plant tissue was collected to determine the nutrient content. The strawberry crop was followed by a second crop of zucchini squash. For Objective 1c, in July of 2022, Hong, Desaeger, Rosskopf, and Zhao teams initiated two coordinated ASD field trials to examine the pre-plant application rates of molasses and organic nitrogen fertilizer for optimizing the effectiveness of ASD in strawberries. The experiments were established on certified organic land at the UF/IFAS Plant Science Research and Education Unit (PSREU) in Citra, FL and at the UF/IFAS Gulf Coast Research and Education Center (GCREC) in Wimauma, FL. Sunn hemp was planted as a cover crop at the seeding rate of 44.9 kg/ha in early July at both locations and its termination is scheduled for early September followed by the ASD treatment implementation prior to strawberry planting. **Publications** - Type: Book Chapters Status: Published Year Published: 2022 Citation: Desaeger, J, Williams K, and Rosskopf, E. 2022. Organic Management Strategies for Nematode Control in Florida Plasticulture, pp. 293-325. In K. K. Chaudhary, M. K. Meghvansi (eds.), Sustainable Management of Nematodes in Agriculture, Vol.1: Organic Management, Sustainability in Plant and Crop Protection 18, https://doi.org/10.1007/978-3-031-09943-4_12. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Di Gioia, F. 2022. Anaerobic Soil Disinfestation (ASD) for Organic High Tunnels. Mid-Atlantic Fruit and Vegetable Convention Proceedings. (pp. 126-127). Richfield, PA: Pennsylvania Vegetable Growers Association. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Balaguer, R., Di Gioia, F., Rosskopf, E. 2022. Evaluating Carbon Sources for Anaerobic Soil Disinfestation (ASD) in High Tunnel Production in Pennsylvania. Mid-Atlantic Fruit and Vegetable Convention Proceedings. (pp. 44). Richfield, PA: Pennsylvania Vegetable Growers Association. - Type: Journal Articles Status: Published Year Published: 2022 Citation: Fernandez-Bayo, J., Achmon, Y., Guerrero, M.D.M. and Di Gioia, F. 2022. Editorial: Upcycling organic waste for the sustainable management of soilborne pests and pathogens in agri-food systems. Front. Sustain. Food Syst. 6:1012789. - Type: Websites Status: Published Year Published: 2021 Citation: https://eorganic.info/ASDEasyOrganic - Type:

Theses/Dissertations Status: Accepted Year Published: 2022 Citation: Balaguer Barbosa R. 2022. Upcycling By-products of the Agri-food Industry as Carbon Sources for the Application of Anaerobic Soil Disinfestation in Pennsylvania Vegetable Production Systems. Master of Science Thesis. The Pennsylvania State University. - Type: Book Chapters Status: Awaiting Publication Year Published: 2023 Citation: Rosskopf, E. and Di Gioia, F. 2023. New Approaches to Soil Disinfestation for Specialty Crops. In W.H. Elmer, M. McGrath, R.J. McGovern (Eds.), Handbook of Plant Disease Management. Handbook of Vegetable and Herb Diseases. Springer, Cham. ISSN: 2509-4823. In press. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Erin Rosskopf, Jason Hong, Francesco Di Gioia, Raymond Balaguer Barbosa, Xin Zhao, Isaac Vincent, Nan Xu, Natalia Peres, Johan Desaeger, David Moreira Calix, Juliana Baggio Silveira, Joji Muramoto, Kaydene Williams, Ole Becker, Antoon Ploeg, Philipp Simon, and Carol Shennan. 2022. Progress and Pitfalls in the Development of Non-chemical Soilborne Pest Control. Proceedings of the 2022 Methyl Bromide Alternative Outreach Conference. Maitland, FL November 1-4, 2022.

↑ Return to Index

Addressing Incongruities Between Food Safety Management and National Organic Program Standards

Accession No.	1026662
Project No.	RI001001
Agency	NIFA RI.\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34893
Proposal No.	2021-02900
Start Date	01 SEP 2021
Term Date	31 AUG 2022
Grant Amount	$49,998
Grant Year	2021
Investigator(s)	Baur, P.; Shade, JE, .
Performing Institution	UNIVERSITY OF RHODE ISLAND, 19 WOODWARD HALL 9 EAST ALUMNI AVENUE, KINGSTON, RHODE ISLAND 02881

NON-TECHNICAL SUMMARY

Food safety is a major concern for the entire specialty crop industry, yet while all food producers are subject to food safety rules, organic farmers can face unique costs and challenges in trying to meet both National Organic Program standards and food safety requirements. For instance, organic farmers must support biodiversity, but some food safety concerns pressure them to limit habitat and wildlife on or near the farm. Other incongruities include the use of biological soil amendments of animal origin (BSAAOs), inasmuch as these amendments are perceived as food safety risks, and water sanitizing treatments that conflict with allowable substances for organic certification. While the organic community has identified this as a critical issue, little data has been collected synthesizing the current experiences and specific research needs of the organic community. This planning grant will fill this gap by conducting a needs assessment utilizing a national survey and convening a multi-stakeholder summit to pinpoint the most challenging incongruities between food safety and NOP policies. These activities will determine which producers are most impacted (product sectors and regions), which food safety requirements are most difficult to synchronize with NOP standards, and prioritize which research opportunities can best address these specific conflicts. The long-term goal of this proposal is to provide organic growers and industry members with cost-effective and organic-compliant tools to mitigate food safety risk and retain third-party certification. Specifically we aim to collaborate with organic farmers, certifiers and researchers to develop a full OREI research proposal for 2023 submission.

OBJECTIVES

Organic farmers can face unique costs and challenges in trying to meet both National Organic Program standards and food safety requirements. While the organic community has identified this as a critical issue, little data has been collected synthesizing the current experiences and specific research needs of the organic community. This planning grant will fill this gap by conducting a needs assessment to pinpoint the most challenging incongruities between food safety and NOP policies. Our long-term goal is to develop research programs that reduce the burden of compliance with multiple regulations, largely by equipping organic farmers and industry stakeholders with feasible, cost-effective, and organic-compliant tools to comply with food safety best practices and requirements. Our specific objectives are to: Gather current information on organic growers\'

experiences with incongruities between food safety requirements and organic standards; Assess the target audience\'s priorities related to research on reducing incongruities between food safety and organic agriculture; Conduct a systematic review of published data and ongoing research activities related to the identified priority needs; Identify gaps between priority needs and the current state of the science; and Develop a full multi-regional OREI research proposal to address those gaps to be submitted in 2023.

APPROACH

This planning grant will conduct a needs assessment of organic farmers faced with tensions related to regulatory compliance of NOP and Food Safety risk mitigation requirements. The study will quantify and characterize the current challenges and needs of farmers by using a survey and direct dialogue with organic stakeholders. The survey results will culminate in a virtual workshop for organic stakeholders so that public comment can be solicited and incorporated into the development of a full research proposal. To help guide the proposed project and extend our reach throughout the U.S. organic community, we have assembled a multi-disciplinary, multi-institutional advisory committee. Specifically this assessment will gather information on: (1) organic growers\' experiences with food safety requirements, (2) specific conflicts encountered with NOP standards, (3) costs and burdens of compliance, (4) types and amounts of losses from safety concerns, (5) strategies organic farmers have undertaken to co-manage food safety with organic farming standards, and (6) research needs for assessing food safety risks and developing or validating new food safety techniques and technologies. The needs assessment will be conducted in six tasks, listed below. The target audience includes a variety of stakeholders: farmers, handlers, certifiers and research experts working with food safety and/or organic crops. Task 1: Convene the Core Team and Advisory Committee. Our first task is to convene our Core Team of Co-PIs and Co-investigators (Pages 2-4) and engage our diverse range of stakeholder advisors (Appendix 1). To address the unique food safety management challenges facing the organic sector, we have developed a strong interdisciplinary team of experts across multiple disciplines. The Core Team will attend bimonthly meetings to develop the national survey and help organize the research development workshop. The Advisory Committee will be offered an advanced draft of the survey for comment and will also assist in the organization of the research development workshop. The Advisory Committee will expand the reach of the survey and its results through their farmer networks. Task 2: Develop and implement a national survey and discussion groups. Dr. Baur, with input from the Core Team and Advisory Committee, will develop a web-based survey to gather data on the six needs assessment areas listed above. In collaboration with Washington State University\'s Social and Economic Sciences Research Center (SESRC, the largest survey research center in the western U.S.), Dr. Baur will distribute the survey to organic producers, certifiers and industry members (buyers). Our proposal and survey instrument will be submitted to the Washington State University\'s Institutional Review Board (IRB) in compliance with federal regulations to protect the rights and welfare of human subjects involved in the research. Task 3: Conduct a systematic review of published data and ongoing research activities related to the identified priority needs. The core team, in conversation with the advisory committee, will conduct a systematic review of the extensive published literature on organic agriculture and food safety that already exists in order to synthesize the \"state of the science\" on evidence-based food safety interventions and their effectiveness. A detailed search of USDA NIFA\'s Current Research Information System (CRIS) will also be performed to catalog active and ongoing research into organic-friendly/organic-compliant interventions for food safety that has not yet been published. From this synthesis, gaps will be identified between existing and ongoing research and what the needs identified by the organic community via the assessment survey. Task 4: Host a virtual research development workshop to narrow research priorities and plan for a full research proposal. The core team, advisory committee members, and additionally recruited farmer participants and/or their representatives will convene for a 2 day-long virtual workshop hosted by The Organic Center. The virtual technology platform to be used will offer hands-on interaction by all meeting participants, it will support video presentations and slideshows, and will offer breakout rooms for smaller, themed discussions as needed. The overall goal of the workshop will be to develop an integrative research plan to submit as a full OREI proposal in 2023. To achieve this, we have five main objectives: 1) Present research priorities identified by the national survey and farmer roundtable discussion, 2) Present on-farm experiences through video presentations, 3) Narrow the focus to a handful of questions with testable hypotheses for which a full research project could be developed by a core research team, 4) Form appropriate academic sub-teams who could study the identified research questions in a multi-regional setting, and 5) Obtain commitment from academic team members to lead the writing and submission of a full proposal. Task 5: Communicate findings to the organic community via webinar and white paper. The Organic Center will host a webinar to present the survey findings to the organic community and solicit additional comments to inform the research development workshop. Webinars presented by TOC in 2020 received an average of 460 registrants. The webinar comments will be compiled and presented at the research development workshop. After all main activities, a final report will be generated as a white paper and distributed to organic stakeholders, publicized through similar channels as the survey to reach a broad audience. Task 6: Core research team will

meet to write and submit a full OREI proposal. Progress 09/01/21 to 08/31/22 Outputs Target Audience:This is a stakeholder-led project, as organic fruit and vegetable farmers identified the initial concept for this food safety needs assessment among organic specialty crop growers. During the this planning project, we engaged with organic fruit and vegetable farmers in four ways: (1) directly participating in the project team (2 farmers), (2) participating in the project's advisory committee; (3) participating in listening sessions held by the co-PDs at various organic grower meetings around the country; and (4) through a national, online needs assessment survey. A secondary audience for this planning grant project has been scientists and other researchers working in related areas. So, for example, our team was in active discussion with a complementary project based out of Kansas State University and focused on post-harvest food safety for organic farmers. 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?We have engaged in outreach activities regarding the need for research into and policy engagement on this topic through both the survey instrument\--which includes an introductory message explaining the purpose and objectives of this project\--and through our listening sessions, which provide a more conversational format for interfacing with communities of interest, namely organic farmers. Based on results of the survey and listening sessions, we prepared a report onpriorities related to research on reducing incongruities between food safety and organic agriculture that was publicly presented through an online webinar hosted by The Organic Center with support from the Organic Trade Association on August 10, 2022. We had over 60 attendees. A recording of the webinar is publicly available here: https://www.organic-center.org/tools-organic-farmers-need-meet-food-safety-requirements-learnings-national-needs-assessment. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Gather current information on organic growers' experiences with incongruities between food safety requirements and organic standards; We developed an online, national needs assessment survey instrument in consultation with our advisory committee and the Survey Research Center at Washington State University, which began collecting survey responses in February, 2022. Two distribution methods were used: (1) direct email outreach to \~3,600 US organic fruit/vegetable farmers identified through the national USDA Organic Integrity Database; and (2) indirect outreach, i.e. convenience sampling, through sectoral and regional listservs with high proportions of organic grower members. We received 341 responses, of which 181 fit the filtering criteria for inclusion in the needs assessment. We conducted listening sessions on organic growers' experiences with incongruities between food safety requirements and organic standards with organic farmers at four grower meetings including at the Organic Trade Association Produce Council, the Organic Grower Summit, the MOSES meeting in Iowa, and the Organic Association of Kentucky. Assess the target audience's priorities related to research on reducing incongruities between food safety and organic agriculture; Based on results of the survey and listening sessions, we prepared a report on priorities related to research on reducing incongruities between food safety and organic agriculture that was publicly presented through an online webinar hosted by The Organic Center with support from the Organic Trade Association on August 10, 2022. We had over 60 attendees. A recording of the webinar is publicly available here: <https://www.organic-center.org/tools-organic-farmers-need-meet-food-safety-requirements-learnings-national-needs-assessment>. Conduct a systematic review of published data and ongoing research activities related to the identified priority needs; Work on this objective is ongoing leading up to submitting a full multi-regional, Tier 1 OREI research proposal (see 5 below). Identify gaps between priority needs and the current state of the science; and Work on this objective is ongoing leading up to submitting a full multi-regional, Tier 1 OREI research proposal (see 5 below). We are collaborating with another team of researchers who conducted a food safety evidence synthesis study to triangulate between research, outreach, and extension priorities identified in our needs assessment and the current state of the science. Develop a full multi-regional OREI research proposal to address those gaps to be submitted in 2023. We held an initial planning meeting (12 in attendance) in mid-October, 2022 to sort through results from the activities described above and consider feedback from the August webinar. Two broad objectives for research, extension and outreach were identified. A second proposal planning meeting will be held in November, 2022, to further hone these objectives, identify key collaborators, and begin the proposal writing process. Publications

↑ Return to Index

Sustainable, High-quality Organic Pulse Proteins: Organic Breeding Pipeline for Alternative Pulse-based Proteins

Accession No.	1026666
Project No.	SC-2021-02927
Agency	NIFA SC.\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34895
Proposal No.	2021-02927
Start Date	01 SEP 2021
Term Date	31 AUG 2025
Grant Amount	$1,227,675
Grant Year	2021
Investigator(s)	Thavarajah, D.; Kresovich, ST, .; Boatwright, JO, LU.

NON-TECHNICAL SUMMARY

Organic plant-based proteins are popular because they are a clean source of protein without added chemicals. Contrary to consumer perception, organically grown pulse crops have lower protein content. This low protein content makes organic pulse proteins expensive, and cultivars bred for non-organic production are often not suited to organic protein production. The organic ingredients possess better protein quality, digestibility, color, texture, and flavor than conventional pulse proteins. These quality traits need to be included in the breeding pipeline to develop future organic cultivars suitable for organic pulse-based protein production. Our long-term goal is to breed field pea and lentil cultivars suitable for organic production with higher protein quality, digestibility, color, texture, flavor, and better adaptation to protein isolation. This project is built on our previous OREI and Good Food Institute-funded projects to refine the breeding pipeline to develop protein-biofortified organic pulse cultivars for plant-based protein applications that will lead to economically rewarding sustainable organic farms. The objectives of this project are to (1) develop protein-enriched organic field pea and lentil varieties using on-farm field selection, (2) combine genomic information and protein trait mapping to enable the best genotype-to-phenotype mapping, and (3) develop on-farm educational and extension activities using the existing Clemson University (CU) \"Going Organic portal,\" Carolina Farm Stewardship Association, Good Food Institute, and e-Organic platform. This project is aligned with the OREI goals to (1) develop and improve organic agriculture production, breeding, and processing methods; (2) determine desirable traits; and (3) develop new and improved seed varieties for organic agriculture.

OBJECTIVES

Supporting Objectives: Develop a breeding pipeline for protein-enriched organic field pea and lentil varieties using on-farm field selection to (i) increase crop adaptation toward sustainable organic farming systems and (ii) improve protein quantity and quality (sulfur amino acid balance, protein digestibility, color, texture, aroma, and flavor) toward plant-based protein production. Combine genomic information and protein trait mapping to enable the best genotype-to-phenotype mapping and lead to future breeding of high protein quality cultivars with increased economic returns. Develop on-farm educational and extension activities using the Clemson University (CU) \"Going Organic,\" Carolina Farm Stewardship Association (CFSA), Good Food Institute (GFI), and eOrganic resources.

APPROACH

Plant Material: For the on-farm selections, \~49 lentil elite cultivars in production and advanced breeding line accessions from the USDA-ARS and ICARDA breeding programs will be used. For the association mapping study, a \~361-member lentil Global Diversity Panel (LGDP) from ICARDA with a diverse population structure and familial relationship will be used for gene discovery. Field pea on-farm trials have been finished, and the same seeds will use for protein trait phenotyping. Experimental design: In years 1 and 2, the \~49 lentil cultivars and advanced breeding lines will be planted in a complete α-lattice field design with commercial checks with three replicates at two on-farm locations in SC and NC (n=588). Cultivars will be sown in 1.2 m × 6 m plots at a rate of 90-95 seeds/m2 and a seeding depth of 5-7 cm. Each plot will contain four rows spaced 30 cm apart. On-farm variety performance will be evaluated using days to flower, days to harvest maturity, pods/peduncle, pod height, plant height, canopy height, 1000-seed weight, and grain yield. All field evaluations will record diseases, insects, and weeds every week using a scale developed by the Clemson Organic Pulse Breeding program. Protein Quality Analysis: Proteins will be extracted using 10-20 g of organic lentil and field pea seeds from the on-farm trials. The isolation procedure for organic field pea proteins and related composition has been filed as a provisional patent (US patent 63/106,015) by the PI\'s team. Genotyping: Illumina sequencing for the advanced field pea/lentil cultivars will be conducted in year 1. Processing raw sequencing data will be carried out in TASSEL. Genetic variants \i.e., single nucleotide polymorphism (SNP) markers\ identified from genome-wide association mapping (GWAS) will be analyzed in advanced lines and hybrids to determine the number of favorable alleles at each informative marker site (i.e., locus). On-farm results from years 1 and 2 will determine the prediction accuracy and utility of genomics in organic grain breeding. Data Analysis: Raw phenotypic datasets from each location will be compiled in years 1 and 2 after completing grain quality analyses. Broad-sense heritability estimates will be calculated from multiyear data generated from both field sites. Spearman correlation coefficients and rankings will be generated to understand interrelationships among production and quality traits. ANOVA will be performed to understand the individual effects of genotype, environment, and genotype-by-environment interaction. Based on previous work under conventional management, yield and quality traits are anticipated to be highly heritable. Under this hypothesis, genetic analysis will be important to leverage advanced genomic technologies (e.g., genomics-assisted breeding) to increase genetic gain and breeding efficiency and rapidly develop varieties suited for organic production and management systems. Objective 2: Develop and utilize public genomic resources to identify marker-trait associations and advance economically efficient, high-protein-quality cultivars. Plant Material: A \~361-member LGDP from ICARDA, including the base collection of lentil germplasm maintained at the USDA-ARS, will be used to generate genomic resources and identify marker-trait associations (MTAs).Field design: The field design for the LGDP will be similar to Objective 1. These accessions will be planted in a complete α-lattice field design with commercial checks with three replicates at two on-farm locations in SC and NC for two years (n=1083 per location). Each incomplete block is augmented with CDC Redberry (check cultivar for lentil genome) at random positions to reduce special variability. LGDP collection seeds will increase from single plants at CU USDA Organic certified fields in 2021 before planting at on-farm locations, including WP Rawl and Sons (Pelion, SC) and Lomax Farm (Concord, NC).Genotyping: As a recently developed lentil reference genome is now available (https://knowpulse.usask.ca/lentil-genome), lentil researchers are able to develop foundational genomic resources for use in current and future breeding initiatives. To that end, a genomic resource composed of 361 lentil accessions from the LGDP will be built by performing whole-genome sequencing using an Illumina NovaSeq 6000 system to obtain 10× coverage in years 1 and 2 of this project. Accessions will be sequenced using lyophilized leaf tissue grown in a controlled greenhouse. Sequencing data will be aligned to the V1.2 lentil reference genome and processed according to Genome Analysis Toolkit (GATK) best practices (McKenna et al. 2010; DePristo et al. 2011) to maintain data quality standards and metadata descriptions of the experiments and promote reproducibility of the results.MTAs: Raw phenotypic datasets from each location will be compiled in years 1 and 2 after completing protein quality analyses (amino acid quality, color, texture, flavor). Broad-sense heritability estimates will be calculated from multiyear data generated from all four field sites to determine the degree to which genetic factors contribute to the quantity, quality, and profile of lentil proteins. Spearman correlation coefficients and rankings will be generated to understand the associations between production and quality traits. As most agronomic traits of interest are regulated by many loci, where each locus confers an effect of varying magnitude and range on a given trait, experiments must be designed to capture a broad range of genetic effects. High-density markers will facilitate the fine-grained resolution of informative markers via GWAS. GWAS will be performed using tools such as GAPIT and GEMMA, which allow for the rapid execution of an array of models. Statistical analyses of the PSPPC and LGDP will use linear mixed models to account for relationships among individuals within the panels and control the false-discovery rate. Associated genetic variants (i.e., SNP markers) will be used to identify favorable alleles and putatively causative genes using knowledge of genes in linkage disequilibrium. Objective 3: Develop on-farm educational and extension activities using CU \"Going Organic,\" CFSA, GFI, and eOrganic resources.Communication Methods: Communication methods include writing news releases, producing videos, and creating audio files. Outlets for disseminating this material include a webpage, social networks, radio stations, television stations, and print

media. A webpage has been created on the Clemson Public Service and Agriculture website to house print articles and video files https://www.clemson.edu/cafls/organic-breeding/orei/index.html).Education Activities: The PI\'s ongoing organic education initiative has three components: (1) incorporate undergraduate students through CU\'s Creative Inquiry (CI; https://www.clemson.edu/centers-institutes/watt/creative-inquiry/)) and University Professional Internship and Co-op (UPIC) programs; (2) recruit local, regional, and national high-school students who are planning to attend the College of Agriculture, Forestry, and Life Sciences (CAFLS) at CU via the SC Commissioner\'s School, SC Governor\'s School, and Emerging Scholar Programs; and (3) educate national and international students on organic pulse breeding via the ongoing virtual Organic Plant Breeding Summer Institute. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Target audience: The target audience includes organic vegetable and pulse crop producers (Specialty Crops), food processors, pulse breeders, consumers, chefs, culinary personals, and future generations of plant breeders, including underrepresented SC high school (4-H), graduate students, Plant and Environmental Sciences (PES) undergraduate students, South Carolina (SC) Commissioner School, Creative Inquiry (CI), and University Professional Internship and Co-op (UPIC) programs. These key stakeholders are from local, national, and international audiences from Africa, Asia, Europe and South America. Briefly, (1) Classroom education includes graduate students, undergraduate students, visiting fellows, plant breeders, CI: undergraduate students, beginning, non-traditional farmers, and veterans, an internship program for undergraduate students (first-year students from PES), underrepresented national and international high school students; consumers, food processors, healthcare workers, and local community; 4-H students from SC (middle and high school students); local food and technology industry partners for commercialization of patents and varieties, and global research community (International Food Legume Research Community (IFLRC); North American Pulse Improvement Association (NAPIA), (2) Extension and outreach: growers, food processors, consumers, chefs, restaurant communities, local food communities, marketing personnel, researchers, breeders, and future generations of plant nutritional breeding leaders. Changes/Problems:One of the field locations at Clemson University was destroyed by bad weather, which delayed the planting window. Therefore, we are hoping to add one extra organic on-farm location for advanced breeding lines testing for variety release. What opportunities for training and professional development has the project provided?PD-Thavarajah applied for the nationally competitive program, the Jefferson Science Fellowship, and was selected for the 2024-2025 class of Jefferson Science Fellows, which is the 21st class of Fellows selected since 2003 as an initiative of the Office of the Science and Technology Adviser to the U.S. Secretary of State. This program is designed to build capacity for science, technology, and engineering expertise within the U.S. Department of State and the U.S. Agency for International Development (USAID). PD-Thavarajah will serve USAID from Aug 2024 to Aug 2025 (https://www.nationalacademies.org/our-work/jefferson-science-fellowships/fellows). PD-Thavarajah also obtained training and professional development courses on diversity and equity, conflict of interest, HR/hiring procedures, and the CITI program on human Subjects protection courses, including investigators conducting social and behavioral science research. PD-Thavarajah was the chair of the organizing committee of the 2023 North American Pulse Improvement Association (NAPIA) and Bean Improvement Corporation (BIC) meeting held at Greenville, SC. Senior doctoral student Sonia Salaria was awarded a Wade Stackhouse Graduate Fellowship (2023-2024) and a Graduate student travel award by 2023 BIC/NAPIA. Sonia attended the plant breeding tool workshop for accelerated plant breeding and career-building professional workshops at the NAPIA/BIC meetings. She served as the graduate student representative for the 2023 NAPIA/BIC organizing committee at Greenville, SC. Sonia also served as a teaching assistant to PD-Thavarajah courses to develop professional teaching experience. Further, she attended several coding and computation courses during the reporting period for genomic analysis. Amod Madurapperumage, a doctoral student, and the field manager, Tristan Lawrence, have obtained the United States Department of Transportation - Federal Aviation Administration (part 107) license and Training to fly UAVs from geospatial information services at Clemson University, SC. Amod won the Graduate student oral presentation competition (2nd place) at the 2023 NAPIA/BIC conference - in Greenville, SC. Amod attended several professional development training sessions for high-throughput phenotyping from Phenome Network, Texas-AM, and Agilent Technologies. Two other doctoral students and the visiting postdoctoral fellow attended the NAPIA/BIC and the NAPB conferences and presented their research posters. Mark Dempsey won first place in the graduate student poster competition at the 2023 BIC/NAPIA. High school student activities include attending STEM sessions. These workshops include Mendelian breeding games, phenomics, mendelian laws, food tasting, and cooking experiences for the farm-to-table approach. Dr. Thavarajah offered a fall three-credit creative inquiry (CI) course and the University Professional Internship and Co-op (UPIC) course. These classes have four modules: i) hands-on breeding experience, ii) phenomics techniques, iii) building healthy food systems, and iv) developing a pulse cookbook. At the end of the semester, these students presented their projects at the CI Undergraduate Research Symposium, NAPIA/BIC meetings and honors college research symposium. The Organic Pulse Breeding team, including graduate students, undergraduate students, postdoctoral fellows and staff, had several workshops with the industry partners related to this project, including pulse growers, SC Department of Agriculture, SC Research Authority (SCRA), Ardent Mill, Anson Mill, WP Rawls and Sons, Agilent technologies from the UK, Clemson University Research Foundation (CURF), and several tech

companies from SC, France, and Canada. How have the results been disseminated to communities of interest?Protein quality and grain yield rankings by genotype have been distributed to stakeholders via the grower meetings. On-farm results were disseminated directly to stakeholders (food processing, consumers,and marketing) using multiple social media outlets - website, YouTube, and social media. As such, Mr. Cory Tanner fromClemson Extension has regularly coordinated data releases and publications in addition to updating social media networks. Dr. Erin Clayton has coordinated protein quality data release to the plant-based food processing and manufacturingcommunity. We developed a new global partnership with FoodShot Global for precision protein. The results have beenpresented at the NAPIA meeting to update the pulse research community and communicated to national and localstakeholders via board meetings, peer-reviewed publications, webinars, and workshops. What do you plan to do during the next reporting period to accomplish the goals?The project team will continue the work related to all three objectives. Impacts What was accomplished under these goals? Our project aims to breed protein-enriched field pea and lentil cultivars for southeast organic cropping systems. Three breeding cycles are ongoing for organic field peas -15-20 crosses were made for each breeding cycle. For the fourth breeding cycle, 25 crosses will be carried out in fall 2024. In the 2023 fall, F4:6 plots (162) and parental plots (22) were threshed, the F4:7 seed was cleaned, and then nutrient lab analyses were conducted for each plot using FT-MIR for nutritional traits. F4:7 seed of 162 composited 2023 field plots (representing twelve 2020 cross populations) were cleaned and analyzed for protein, resistant starch (RS), total starch (TS), and protein digestibility using 1-2 seeds. Seed coat color and seed size were also determined for each of the 162 F4:7 breeding lines. Four 2024 Breeder Preliminary Tests (2 replications each) using a 7x7 lattice field design with 40 (T-1 and T-2) or 41 breeding lines (T-3 and T-4) in each test were planted at W.P. Rawl Farm, SC. For the 2025 field season, early generations will be selected for protein, sulfur-containing amino acids (SAAs), and digestibility using a high-throughput phenomics platform. Organic cultivars will be released in 2025-2026 after two years of yield trials at the organic on-farm locations. Dry pea seed yields were 3833 kg/ha. Seed protein ranged from 17 to 30%, with 80-85% protein digestibility. Total prebiotic carbohydrate concentrations ranged from 14.7 to 26.6 g/100 g; a 100-g serving of organic dry pea provides 73-133% of the recommended daily allowance. In collaboration with Dr. Diego Rubiales (Institute for Sustainable Agriculture, Spain), 58 breeding populations (F3-F8) were evaluated for 2023 and 2024 field seasons, and selected lines will be tested in 2025 for dual release in the USA and Spain. After the MTA with Spain and Clemson University, 7-8 F8 lines were selected for the 2024 fall crosses. Lentil heat-tolerant (\~143-member) and global mapping (129-member) populations from ICARDA were screened to develop climate-resilient cultivars with improved protein quality and digestibility (under the international treaty agreement with ICARDA and Clemson University). This panel had six sub-groups. The mean concentration of 17 different amino acids (AAs) was quantified, including the SAAs methionine (0.21%) and cysteine (0.22%). Fifty significant SNPs were associated with 17 traits of AAs and protein digestibility. The Lentil association mapping panel (LAMP), composed of 446 accessions, was evaluated for protein quality with agronomic adaptation. LAMP has been evaluated under greenhouse conditions for two years using a complete randomized experimental design. In 2024, LAMP was planted in the fields at two locations in South Carolina. The experiment was an α-lattice design with two replications per location and the check CDC Maxim. The data collection for agronomic traits (days to germination, days to flowering, days to maturity, plant height and height of the lowest pod) and protein quality traits (protein, sulfur-containing amino acid concentrations and protein digestibility) has been in progress. The lentil accessions with early maturity, tall plant height, good yield and protein quality have been found and used for the lentil crossing block. Fifteen parents were used for 27 crosses. The panel has also been genotyped, and the sequencing data will be processed and utilized to conduct GWAS in the fall of 2024. 96 LAMP accessions (not genotyped earlier) were genotyped with 10x coverage, and genotyping data analysis is in progress. The preliminary quality check for the genotyping data has been completed. Non-destructive phenotyping tools have been developed to measure eight nutritional traits from one scan for speed breeding. Fourier transform mid-infrared (FT-MIR) spectroscopy is a high-throughput, cost-effective method to quantify nutritional traits. FT-MIR spectroscopy coupled with an attenuated total internal reflectance sampling interface was used to develop multivariate models to measure protein, SAAs, TS, RS, fats, saturated fats, unsaturated fats, and moisture concentrations in a 30-s scan. Total N data from combustion analysis and SAA data from high-performance liquid chromatography (HPLC) analysis following acid hydrolysis were used for model calibration and validation. We used FT-MIR spectroscopy to screen the early generations (F2 and F5) to speed up the selection process. Chemometric models were developed with partial least square regression (PLSR) to determine total proteins and protein digestibility in field peas and lentils and, further, total fatty acids. These regression models had 70 % of samples for calibration and 30 % for validation. We have developed infrared (IR) cameras and unmanned aerial vehicles (UAVs) to select the best breeding populations in the field and greenhouse. High throughput phenotyping is further required for agronomic traits (i.e., plant height, lodging, days to maturity etc.). Remote sensors based on unmanned aerial vehicles (UAVs) are used to phenotype agronomic traits. For high-throughput phenotyping, spectral details can be unpacked and processed with photogrammetry tools, such as crop surface modeling (CSM) and normalized difference spectral indices. Accordingly, a photogrammetry study with remote sensing has been initiated on field pea breeding plots. A

Phantom 4 UAV with a 20-megapixel camera was employed to collect images. The UAV was flown across Rawls farm (Advanced trials (F7): 24.3 m x 162.5 m) and Cherry Farm (Advanced trials (F7): 42.6 m x 54.8 m) fields at Pelion (33.7946 0N, 81.2713 0W) and Clemson (34.6527 0N, 83.8360 0W). Images were collected at 25 m and 30 m per location. These images were subjected to ortho mosaic to generate 2D maps to extract appropriate spectroscopic indices for photogrammetry modeling the agronomic traits above. For 2023-2024, 6 high school student workshops (Pulses 4-Health: Science of Peas, Lentils & Chickpeas) for 4-H were conducted, covering 200-250 students. The annual 2024 field day was conducted at the WP Rawls on-farm location in Pelion, SC, and 62 participants attended the field workshop. \>120 extension activities, including training programs, short courses, workshops, presentations, meetings and farm contacts related to the project, were completed for the 2023 -2024 reporting time. The Thavarajah team organized an \"Eat Pulses\" workshop for consumers and the CU health team\--this involved pre-and post-tests after lectures, round table discussions, and cooking experiences at the CU kitchen. Barriers to pulse consumption were discerned, with half the attendees indicating pulses were not part of their usual (habitual) food intake, almost one-third reporting the long cooking time was a barrier, and one-fifth noting they were unfamiliar with preparation and recipes. Less common barriers included not liking the taste and having gastrointestinal upset. Attendees were open to learning more, especially after attending this workshop and tasting authentic pulse dishes, and all were open to having pulse ingredients in their regular foods. The attendees were convinced the benefits of pulses, including health effects and reduced cost compared to animal protein, would be necessary for those with limited incomes. Regular courses were carried out for undergraduate students, including the Creative Inquiry and UPIC Internship programs. Students attend North American Pulse Improvement Association and National Association of Plant Breeders meetings, present their research, and publish a pulse cookbook in 2024. The program appeared on public radio, TV, and in several news publications on organic pulse breeding. This project trains five doctoral students (two new students), three research associates, two full-time technicians, two postdoctoral fellows, and \> ten undergraduates. Substantial extension and outreach activities were done, and three new utility patents were submitted. Publications Type: Journal Articles Status: Published Year Published: 2023 Citation: Amod Madurapperumage , Nathan Johnson, Pushparajah Thavarajah, Leung Tang, Dil Thavarajah!, 2023. 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These key stakeholders are from local, national, andinternational audiences from Africa and Asia. Briefly, (1) Classroom education includes graduate students, visiting fellows,plant breeders, CI: undergraduate students, beginning, non-traditional farmers, and veterans, an internship program forundergraduate students (first-year students from PES), underrepresented national and international high school students;consumers, food processors, health workers, and community; 4-H students from South Carolina (middle and high schoolstudents); and global research community; (2) Extension and outreach: growers, food processors, consumers, marketingpersonnel, researchers, breeders, and future generations. Changes/Problems:Two North Carolina on-farm locations were dropped due to the weed and disease pressure. We will continue to focus on organic pulse breeding for SC. Other than the weather conditions, we are not expected to change any of the planned work for 2024. What opportunities for training and professional development has the project provided?Four doctoral students, one master\'s student, four undergraduates, two postdoctoral fellows, a part-time breeder, a food processing research scientist, a full-time field technician, and a lab technician were trained in this project. One doctoral student (Nathan Johnson) and a master\'s student (Tony Reta) graduated in Aug 2022. A master\'s student becomes an assistant breeder at a large vegetable company in California. Dr. Nathan Johnson is a postdoctoral fellow and starting medical school in Aug 2023. In the past year, Dr. Johnson has submitted two first-author articles, has published one co-authored article, and is a co-author on several articles under preparation and review. He has also helped plan and administer several field days and workshops offered by our breeding program, including serving as the master of ceremonies for one. He has attended several R and Python workshops offered by Clemson\'s Research Computing and Data Engagement team. He is currently teaching an informal class for lab members on bioinformatics using R and Linux command line. Dr. Johnson also developed the Breedbase. Both doctoral students and a new postdoctoral fellow attended the 2023 National Association of Plant Breeders Conference and presented their work. High school student activities include attending STEM sessions via the Commissioner\'s School (SC) and 4-H (SC). These workshops include Mendelian breeding games, phenomics, and cooking experiences for the farm-to-table approach. Dr. Thavarajah offered a fall three-credit creative inquiry (CI) course and the University Professional Internship and Co-op (UPIC) course for seven undergraduate students. These classes have three modules: i) hands-on breeding experience, ii) phenomics techniques, and iii) building healthy food systems. At the end of the semester, these students will present their projects at the CI Undergraduate Research Symposium. How have the results been disseminated to communities of interest?Protein quality and grain yield rankings by genotype have been distributed to stakeholders via the grower meetings. Aftercomplete data analysis, On-farm results will be disseminated directly to stakeholders (food processing, consumers, andmarketing) using multiple social media outlets - website, YouTube, and social media. As such, Mr. Cory Tanner from ClemsonExtension has regularly coordinated data releases and publications in addition to updating social media networks. Dr. ErinClayton has coordinated protein quality data release to the plant-based food processing and manufacturing community. Wedeveloped a new global partnership with FoodShot Global for precision protein. The results have been presented at theNAPIA meeting to update the pulse research community and communicated to national and local stakeholders via boardmeetings, peer-reviewed publications, webinars, and workshops. What do you plan to do during the next reporting period to accomplish the goals?We will continue the work related to all three objectives in the proposal. Impacts What was accomplished under these goals? Objective 1: Dry pea: breeding cycle 1: F1 seeds were increased in 2021 using single seed descent (SSD), F4 nurseries were planted, and F6 progenies were tested in 2023 and selected for yield testing in 2024. F5 seeds were selected for protein quality and to advance (F5-F8) to release organic cultivars in 2025. Dry pea seed yields were up to 3833 kg/ha. Seed protein ranged from 17 to 30%, with 80 to 85% protein digestibility. Total prebiotic carbohydrate concentrations ranged from 14.7 to 26.6 g/100 g; a 100-g serving of organic dry pea provides 73.5 to 133% of the recommended daily allowance. Heritability estimates for individual prebiotic

carbohydrates ranged from 0.27 to 0.82. Organic dry peas are rich in minerals (Fe: 1.9-26.2 mg/100 g; Zn: 1.1-7.5 mg/100 g) with low to moderate concentrations of phytic acid (18.8-516 mg/100 g). Selected F4:6 progeny plots (162) were harvested in late May 2023 based on visual appearance for date of maturity, height, lodging resistance, disease resistance, and overall uniform appearance. Single plants were selected from 16 progeny plots segregated for maturity and/or plant height. F4:7 seed will be composited from selected plots. Harvested lines will be further evaluated for seed appearance and compositional traits during Summer and Fall 2023. Selected F4:7 Clemson University breeding lines will be evaluated for seed yield, disease resistance, and general agronomic traits in 2024 field tests in two USDA organic-certified on-farm fields. In cooperation with Dr. Diego Rubiales (Institute for Sustainable Agriculture, CSIC, Avenida Menéndez Pidal s/n, Campus Alameda del Obispo, Spain), fifty-eight breeding populations (F3 - F8) were evaluated in the 2023 Pelion SC on-farm field nursery. Marked differences in disease resistance, particularly powdery mildew, and suitable agronomic traits were observed among the populations. Selected populations will be further evaluated in the 2024 field nursery.Breeding cycle two was established in 2022- eighteen crosses were made in the GH. Parents utilized six commercial cultivars, six high-protein plant introductions (PIs), and two PIs with improved phosphorus uptake. F1 seeds (384) were planted in a GH on February 13, 2023, with resulting F2 seeds harvested from 371 F1 plants from mid-April to mid-May 2023. F2 seed from nine selected crosses is now being advanced F2 - F3 via SSD, with the resulting F4 seed to be planted in the Pelion on-farm field nursery in January 2024. F2 seed from the other nine 2022 crosses of adapted high-protein PI parents will be planted in the field in 2024, with agronomically suitable F2 plants selected for advancement. Breeding cycle 3: F1 seeds are harvested from fifteen crosses made during April-May 2023 in a Clemson GH. There were three commercially available, adapted cultivars, five \"old\" cultivars from the USDA field pea germplasm collection, and one PI. The five cultivars and a single PI from USDA Germplasm Collection were selected based on field evaluations for agronomic and seed composition traits at Pelion, SC (2019) and Clemson, SC (2022). Lentil: For organic lentil breeding, nine lentil cultivars were tested in production in 2022 (3 locations - NC site was dropped due to disease and weed pressure) and 2023 (2 locations), and the lentil global diversity panel with 299 accessions was tested in two locations in 2022 and 2023. Organic lentil breeding is limited due to severe root rot incidences without fungicide treatments. In year 2, nine elite cultivars currently in production were planted at two certified organic locations in Clemson and Pelion, SC. The Pelion trial had the best agronomic performance, adaptability, and yield. Pelion had minimal disease pressure, while Clemson had significant disease pressure, with almost all plots showing a significant loss in the stand. Fifteen lentil parents were selected from ICARDA lentil materials to develop organic cultivars adapted for organic production with short duration, disease resistance, and yield. Twenty-eight possible lentil crosses will be made in Nov 2023. Root rot diseases were the primary production constraint, including Fusarium spp., Verticillium wilt, and an unidentified oomycete. Among the 298 accessions evaluated, 12 accessions combined the favorable characteristics of higher canopy cover (\>10%), disease incidence ≤85% (assessed 74 days after planting), and were mature by harvest: PI 178940, PI 283604, PI 289079, PI 297286, PI 298357, PI 298645, PI 320936, PI 320952, PI 426797, PI 431666, PI 432271, PI 518731 Objective 2: Lentil: A \~143-member lentil heat-tolerant GWAS population and 129-member global mapping population from ICARDA were screened to develop climate-resilient organic lentil cultivars with improved protein quality and digestibility to determine population structure. This panel had six sub-groups, and the mean concentration of 17 different amino acids (AAs) was quantified, including the sulfur-containing amino acids (SAAs): methionine (0.21%) and cysteine (0.22%). Fifty significant SNPs were associated with 17 traits (number of SNPs): alanine (3), arginine (2), aspartate (2), aspartate: TotalAA ratio (7), cystine (7), glutamate: TotalAA ratio (7), glycine: TotalAA ratio (7), histidine: TotalAA ratio (7), isoleucine (1), leucine (3), lysine (3), methionine (7), methionine: TotalAA ratio (7), phenylalanine (2), threonine (1), valine (2), and protein digestibility. The Lentil association mapping panel (LAMP), composed of 446 accessions, was evaluated for protein quality with better agronomy. The LAMP was screened in the greenhouse in a completely randomized design (CRD) with three replications per accession during Spring-Summer 2022 and 2023. The elite lentil germplasm from ICARDA was also obtained, including 15 parents for the crossing program. This germplasm was planted for seed increase in the greenhouse at the end of the fall of 2022. 96 LAMP accessions (not genotyped earlier) were genotyped with 10x coverage, and genotyping data analysis is in progress. The preliminary quality check is in progress for the genotyping data. Pea: Genome-wide association studies have been performed for total protein, sulfur-containing amino acids (SAA), and protein digestibility (PDg). The study included 299 genotypes, of which 267 had been previously genotyped. These were grown in three location years: Clemson 2021, Clemson 2022, and WP Rawls 2020. Total protein ranged from 15.7-36.5%, with a mean of 23.6%. SAA ranged from 0.11-0.56% with a mean of 0.23%. PDg ranged from 81.9-87.4%, with a mean of 84.6%. The BLINK model from GAPIT was used. The analysis was performed on the combined environments as well as individual environments. In summary, 27 unique SNPs were identified across the three traits. Protein had 18 SNPs, SAA had 8 SNPs, and PDg had 1 SNP. Food processing: Three inventions have been developed: 1) an organic protein isolation process, 2) prebiotic carbohydrate enrichment, and 3) liquid protein and carbohydrates for beverages and semi-solid food applications. A US Patent application for invention 1 (#73/106,015), titled \"Methods of isolating plant protein and related composition,\" was published in April 2022. It

describes the isolation of organic proteins to create organic protein compositions balanced with all essential AAs that are highly digestible, free of agricultural residues, and with no added sodium or chlorides. We will use this patented technology to screen advanced breeding lines of pulse crops that provide the highest protein yield, digestibility, and functional food properties to apply in liquid (e.g., milk), semi-solid (e.g., yogurt), and solid (e.g., burgers) food applications. Objective 3: Following were conducted: 9 webinars, four student workshops, three undergraduate courses, a field day, an advisory board meeting, 10-12 extension talks, and a consumer workshop. Approximately 500 stakeholders were reached for organic pulse breeding and nutrition. Publications Type: Journal Articles Status: Published Year Published: 2023 Citation: Dil Thavarajah, Tristan Lawrence, Lucas Boatwright, Nathan Windsor, Nathan Johnson, Joshua Kay, Emerson Shipe, Shiv Kumar, Pushparajah Thavarajah, 2023. Organic dry pea (Pisum sativum L.): a sustainable alternative pulse-based protein for human health. PLoS ONE 18(4): e0284380. https://doi.org/10.1371/journal.pone.0284380. Type: Journal Articles Status: Submitted Year Published: 2023 Citation: Sonia Salaria, J. Lucas Boatwright, Nathan Johnson, Priyanka Joshi, Pushparajah Thavarajah, George Vandemark, Dil Thavarajah!, 2023. Fatty acid composition and genome-wide associations of a chickpea (Cicer arietinum L.) diversity panel for biofortification efforts. Scientific Report. Submission ID c3b96c8f-2d78-45fe-ad8b-da64ca0f29a7 Type: Journal Articles Status: Submitted Year Published: 2023 Citation: Nathan Johnson, Pushparajah Thavarajah, Nathan Windsor, Leung Tang, Dil Thavarajah!, 2023. Fourier-transform infrared spectroscopy (FTIR): an inexpensive, rapid, and non-destructive tool for starch and resistant starch analysis. The Plant Phenome Journal, TPPJ-2023-05-0013-OA Type: Journal Articles Status: Submitted Year Published: 2023 Citation: Nathan Johnson, J Lucas Boatwright, William Bridges, Pushparajah Thavarajah, Shiv Kumar, Dil Thavarajah, 2023. Targeted improvement of plant-based protein: Genome-wide association mapping of lentil (Lens culinaris Medik.) diversity panel. PPP, PPP-MS-2023-00644 Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Sonia Salaria, Dil Thavarajah, 2023. Genome-Wide Association Studies (GWAS) to explore the fatty acid composition of a chickpea (Cicer arietinum L.) diversity panel for biofortification. National Association of Plant Breeders, GV, SC. July 19-20, 2023 Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Van Grouw, N., *Kittel, A., *Terry, A., *Miller, A., *Pussella, K., *Johnson, J., *Windsor, N., Salaria S., Dil Thavarajah, 2023. Fighting Food Insecurity with Innovative Gardening Methods. Poster presentation at Clemson University 18th Annual Focus on Creative Inquiry Forum, Clemson, SC Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Mark Dempsey, Dil Thavarajah, 2023. Adapting and optimizing lentil for organic production in the Southern US. National Association of Plant Breeders, GV, SC. July 19-20, 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Priyanka Joshi, Dil Thavarajah, George Vandermark, 2023. Genome-wide association mapping for seed protein concentration in chickpea (Cicer arietinum L.). National Association of Plant Breeders, GV, SC. July 19-20, 2023. Type: Theses/Dissertations Status: Published Year Published: 2022 Citation: Lentil (Lens culinaris Medik.) Prebiotic Carbohydrates and Protein Quality: Uncovering Genomic Associations and Developing Rapid FTIR Phenotyping Methods Author: Nathan Johnson- http://tigerprints.clemson.edu/all_dissertations/3116 Publication Type: Theses/Dissertations Status: Published Year Published: 2022 Citation: Pre-breeding of Kale (Brassica oleracea var. acephala) Organic adaptation and shelf life Author: Craig Reda- https://tigerprints.clemson.edu/do/search/?q=Kale%20quality&start=0&context=4572410&facet= Publication Type: Other Status: Published Year Published: 2023 Citation: 2023: Thavarajah receives Clemsons 2023 Godley-Snell Award. https://news.clemson.edu/thavarajah-receives-clemsons-2023-godley-snell-award/ Type: Other Status: Published Year Published: 2022 Citation: 2022: Clemson webinar series promotes Going Organic when breeding pulse crops. https://news.clemson.edu/clemson-webinar-promotes-going-organic-when-breeding-pulse-crops/ Type: Other Status: Published Year Published: 2022 Citation: 2022: American Society of Agronomy, Society Science, CSA News, High-Throughput Phenotyping Tool for Protein Biofortification in Pulses. https://doi.org/10.1002/csan.20845 Type: Websites Status: Published Year Published: 2022 Citation: https://www.clemson.edu/cafls/organic-breeding/index.html Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Thavarajah Dil, 2023. Opening talk, Organic Pulse Crop Breeding and Nutrition, \"Eating Pulses\" Workshop, Clemson University, June 10, 2023 Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Thavarajah Dil, 2023, Pulse 101 lecture, Pulse Crop Field day, May 2, 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Thavarajah Dil, 2022. Invited Speaker, Breeding for seeds traits, ASA-CSSA-SSSA, Baltimore, MD, Nov 6-9, 2022 Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Thavarajah Dil, 2022. Invited Speaker, Organic Dry Pea, and Lentil Adaptation to South Carolina for Plant-based Protein Production: NIFA-OREI project update. E-Organic webinar. Oct 20, 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Thavarajah Dil, 2022. Speaker, OREI: Sustainable organic pulses, Organic pulse breeding team meeting, July 28, 2022 Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Thavarajah Dil, 2023. Breeding Biofortified Pulses for human health: A high-throughput phenotyping platform for quantifying nutritional traits. International Conference on Pulses: Smart Crops for Agricultural Sustainability and Nutritional Security, Invited

Talk, New Delhi, India, February 11, 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Thavarajah Dil 2023. Breeding protein enriched organic dry peas, Protein symposium 2023, University of Rwanda, Rwanda. May 2, 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Thavarajah Dil, 2022. Pulse Breeding for Human Health, Invited Seminar, College of Agriculture, Animal Science and Veterinary Medicine (CAVM), Busogo Campus, University of Rwanda, Rwanda. August 20, 2022. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:Target audience:The target audience includes organic producers, food processors, pulse breeders, consumers, and future generations (underrepresented SC high school, graduate, and undergraduate students - Emerging scholars program, SC Commissioner School, Creative Inquiry, and UPIC programs). These key stakeholders are from local, national, and international audiences from Africa and Asia. Briefly, (1) Classroom education includes graduate students, visiting fellows, plant breeders, CI: undergraduate students, beginning, non-traditional farmers, and veterans, internship program for undergraduate students (first-year students from PES), underrepresented national and international high school students; consumers, food processors, health workers, and community; 4-H students from South Carolina (middle and high school students); and global research community; (2) Extension and outreach: growers, food processors, consumers, marketing personnel, researchers, breeders, and future generations. Changes/Problems: Two on-farm locations in North Carolina (NC) were unsuccessful due to the weed and disease pressure. Also, the current lentil cultivars in production are not adapted to climatic conditions in NC. We acquired new germplasm from ICARDA, Morocco, to test in NC, but we are expected to plant dry pea in NC instead of lentils in the 2023 winter. A new organic producer (Del Valle Fresh Inc, Roebuck, SC) will be added as the third on-farm location in SC to test organic lentil and dry peas in the 2023 winter. Other than the weather conditions or COVID-19, we are not expected to change any of the plan work for 2023. What opportunities for training and professional development has the project provided? Three doctoral students, 2-3 undergraduates, part-time technicians, part-time breeders, part-time scientists, and full-time field technicians were trained. >100 high school students attended the breeding workshops. The PD participated in the Breeding for Quantitative Traits in Plants 3-credit course offered by Dr. Rex Bernardo in Spring 2022. Nathan Johnson: From Aug 2021 to Aug 2022, Nathan Johnson analyzed a lentil diversity panel for protein digestibility using an enzymatic assay and sulfur concentration using hydrogen peroxide digestion and ICP spectroscopy. He developed partial least squares models for rapid quantification of protein, sulfur-containing amino acids, resistant starch, and total starch using Fourier Transform Infrared Spectroscopy (FTIR) for pulse crops. He performed genome-wide association studies for protein quality traits and discovered significant genetic markers for 17 of these traits. He also performed admixture analysis and analysis of variance for the lentil diversity panel. Nathan completed one class, \"Pulse Genomics for Nutrition,\" in Spring 2022, led a high school 4-H group event, gave two oral presentations (Clemson Going Organic Webinar series and the North American Pulse International Association Biennial Meeting), and gave two poster presentations (Clemson Growers Meeting and McCall Farms Gift Announcement). He published one co-first-authored paper describing his protein FTIR work and drafted a first-author paper describing his protein GWAS work. He prepared and successfully defended his dissertation on July 14. Sonia Salaria and Mark Dempsey (first year doctoral students) - They have taken regular graduate-level classes, completed first year field and greenhouse studies, developed the lentil association mapping population for protein quality, and currently developing a MAGIC population for lentil protein quality. A UPIC undergraduate intern trained on plant breeding and FTIR technology for protein quality measurement. How have the results been disseminated to communities of interest? Protein quality and grain yield rankings by genotype have been distributed to stakeholders via the grower meetings. After complete data analysis, On-farm results will be disseminated directly to stakeholders (food processing, consumers, and marketing) using multiple social media outlets - website, YouTube, and social media. As such, Mr. Cory Tanner from Clemson Extension has regularly coordinated data releases and publications in addition to updating social media networks. Dr. Erin Clayton has coordinated protein quality data release to the plant-based food processing and manufacturing community. We developed a new global partnership with FoodShot Global for precision protein. The results have been presented at the NAPIA meeting to update the pulse research community and communicated to national and local stakeholders via board meetings, peer-reviewed publications, webinars, and workshops. What do you plan to do during the next reporting period to accomplish the goals?We will continue the work related to all three objectives in the proposal. **Impacts** What was accomplished under these goals? Objective 1: Advanced Lentil Breeding Trial: In year 1 of the organic lentil evaluations, nine elite cultivars in production were planted at three certified organic locations in Pelion, South Carolina (SC), Concord, and Mills River, North Carolina (NC). The Pelion, SC trial was planted on 1 February 2022, and the two NC locations were planted on 15 February 2022. The cultivars were planted in a randomized complete block design with four replicates, one check variety per rep, and encompassed by border plots. The trials were planted using an Almaco cone plot planter, sown into 4.65 m2 (50 ft2) plots with seven rows spaced 7.5 inches apart at a seeding rate of 130 seeds/m2. Agronomic data were collected using the Pheno App' Field Book' to record quantitative and visual assessment data, including germination, vigor, days to flower, days to maturity, canopy height, plant height, the height of the first pod, pods per peduncle, lodging, disease/insect damage, frost tolerance, and canopy closure. Visual evaluations

and qualitative data were given by assigning ratings relative to other test entries over three reps on a scale of 0/1 to 5 according to predefined criteria. The Pelion trial was harvested on 1 June 2022 with an Almaco SPC 20 configured with a platform head. The Concord trial was harvested on 16 June 2022, and the Mills River trial was not harvested due to poor organic management. The seed was stored in a controlled drying barn to attain the optimal moisture content before being weighed, cleaned, sampled, and ground for nutritional analysis. Data analysis for the yield, agronomic traits, and nutritional quality is still in progress. The Pelion trial had the best agronomic performance, adaptability, and yield. The highest yielding cultivars in Pelion were Avondale, CDC Imvincible, and CDC Proclaim. The highest yielding cultivars in Concord were CDC Peridot, CDC Imvincible, and CDC Impala. The three lowest yielding cultivars were the same at both locations, with 'CDC Dazil' as the lowest, followed by 'Pardina' and 'CDC Impress.' The study will be replicated again in 2022-2023 at three locations. LSP: The Lens Single Plant (LSP) collection was increased and evaluated for the first time at the certified organic location in Pelion, SC. The collection comprised 300 accessions from the Lens Single Plant Collection, obtained from the USDA-ARS germplasm in Pullman, Washington. The germplasm collection was planted on 1 February 2022 in an alpha-lattice design into ten-foot plots, consisting of four rows spaced 15 inches apart using an Almaco' head-row' plot planter. Accessions were evaluated on agronomic adaptability and performance using the Pheno App' Field Book' to record quantitative and visual assessment data. The collection was hand-harvested at maturity in increments starting on 20 May 2022 and ending on 3 June 2022. The harvested plants were then moved to a drying barn and threshed with an Almaco Belt Thresher. The seed will be used for protein quality and genomic analysis, and the remaining seed will be planted in 2023. The agronomic and nutritional data analysis will be used to identify accessions with exceptional agronomic adaptability and protein content for parental selection and implementation into the breeding pipeline. The study will be replicated again in 2022-2023 for two locations for the genomic prediction study. PSP: A subset of the Pea Single Plant (PSP) collection was selected and planted on 31 January 2022 at the organic transition farm location in Clemson, SC, to serve as observational plots. Ninety-eight accessions were selected for their high protein content obtained from nutritional analysis from previous trials. The germplasm collection was planted in a randomized complete block design into ten-foot plots, consisting of four rows spaced 15 inches apart using an Almaco' head-row' plot planter. Observational notes and agronomic ratings were recorded and used to identify accessions with desirable traits and adaptability as breeding parents. The trial was hand harvested on 7 June 2022 and moved to the drying barn before being threshed. Seed samples were collected and ground for seed composition nutritional analysis. For breeding cycle 2, Spring of 2022, eighteen crosses were made on protein quality and adaptability. Parents utilized were six commercial cultivars, six high-protein plant introductions (PI's), and two PI's having improved phosphorus uptake under organic growing conditions. The resulting F1 seed has been harvested and planted in the GH and then advanced F2 - F3 via SSD in the GH, with the resulting F4 seed planted in the Pelion field nursery. Objective 2: Phenotyping Pipeline (partnership with the USAID): Fourier-transform mid-infrared (FT-MIR) spectroscopy is a high-throughput, cost-effective method to quantify nutritional traits, total protein, and sulfur-containing amino acids SAA concentrations in plant matter. We used FT-MIR spectroscopy coupled with an attenuated total internal reflectance (ATR) sampling interface to develop multivariate models to measure total protein and SAA concentrations. Total nitrogen (N) data from combustion analysis and SAA data from high-performance liquid chromatography analysis following acid hydrolysis were used for model calibration and validation. Protein Quality and digestibility: A \~143-member lentil heat-tolerant GWAS population and 129-member global mapping population from ICARDA were used for screening to develop climate-resilient lentil cultivars with improved protein quality and to determine population structure for lentils. This panel had six sub-groups. The mean concentration of 17 different amino acids (AA) was quantified, including the sulfur-containing amino acids (SAA): methionine (0.21%) and cysteine (0.22%). Fifty significant SNPs were associated with 17 traits (Johnson & D. Thavarajah in preparation for PNAS, 2023). Lentil Protein Mapping Panel: A lentil association mapping panel (LAMP) composed of 446 accessions was assembled to evaluate high protein quality in cultivated germplasm with better agronomy.The LAMP was screened in the greenhouse in a completely randomized design with three replications per accession during Spring-Summer 2022. LAMP will be genotyped in the fall of 2022 to perform Genome-wide association studies and identify significant SNPs linked to agronomic and protein quality traits. The combined phenotyping and genotyping approach will facilitate the identification of genomic regions impacting the agronomy and quality, providing the best lines for agronomy and quality to develop the lentil breeding pipeline using genomic prediction. Food processing pipeline: We developed three inventions: 1) an organic protein isolation process, 2) prebiotic carbohydrate enrichment, and 3) liquid protein and carbohydrates for beverages and semi-solid food applications. Invention 1 has been submitted to the US Patent and Trademarks Office (#73/106,015), and the other two are undergoing commercial value evaluation at the Clemson University Research Foundation (CURF:#2022-033). The US Patent application is titled \"Methods of isolating plant protein and related composition\" and was published in April 2022. Objective 3: See the accomplishments under the products and other products. We developed a social media outlet, the \"Going Organic\" webinar series, several grower events, and 4-H and SC commissioner school workshops (500 contacts). **Publications** - Type: Journal

Articles Status: Published Year Published: 2022 Citation: Sonia Salaria , Jon Lucas Boatwright, Pushparajah Thavarajah, Shiv Kumar, Dil Thavarajah!, 2022. Protein biofortification in lentils (Lens culinaris Medikus.) toward human health. Frontiers in Plant Science, Plant Breeding 13:869713. 05 April 2022 \| https://doi.org/10.3389/fpls.2022.869713. - Type: Journal Articles Status: Published Year Published: 2022 Citation: Amod Udayanga , Nathan Johnson , Pushparajah Thavarajah, Leung Tang, Dil Thavarajah!, 2022. Fourier-transform infrared spectroscopy (FTIR) as a high-throughput phenotyping tool for quantifying protein quality in pulse crops. The Plant Phenome Journal, 5, e20047. https://doi.org/10.1002/ppj2.20047. - Type: Journal Articles Status: Published Year Published: 2022 Citation: Hasnae Choukri, Noureddine El Haddad, Khawla Aloui, Kamal Hejjaoui, Adil El-Baouchi, Abdelaziz Smouni, Dil Thavarajah, Fouad Maalouf, Shiv Kumar, 2022. High-temperature stress during the reproductive stage effects on grain yield and nutritional quality of lentil (Lens culinaris Medikus). Front. Nutr., 15 April 2022 \| https://doi.org/10.3389/fnut.2022.857469. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Amod Udayanga , Leung Tang, Pushparajah Thavarajah, William Bridges, Emerson Shipe, George Vandemark, Dil Thavarajah!, 2021. Chickpea (Cicer arietinum L.) as a source of essential fatty acids a biofortification approach. Frontiers in Plant Science, Plant Breeding. 12:734980. doi: 10.3389/fpls.2021.734980. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: J Lucas Boatwright, Sarah Powers, Dil Thavarajah, 2021. Developing Genome-wide Resources for Mineral Biofortification of Pea (Pisum sativum L.). North American Pulse Improvement Association, Nov 2-4, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Nathan Johnson, Dil Thavarajah, 2021. Toward a high-throughput molecular breeding pipeline for lentil protein quality. North American Pulse Improvement Association, Nov 2-4, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Amod Udayanga, Dil Thavarajah, 2021. Fourier Transform Mid Infrared (FT-MIR) Spectroscopy as a tool to measure nutritional traits in pulses. North American Pulse Improvement Association, Nov 2-4, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Joshua Kay, Dil Thavarajah, 2021. Are Organic Peas just as Nutritious as Conventional Peas? North American Pulse Improvement Association, Nov 2-4, 2021 - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Sonia Salaria, Dil Thavarajah, 2021. Lentil Protein Biofortification using Conventional Breeding and Association Mapping Approaches. North American Pulse Improvement Association, Nov 2-4, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Mark Dempsey, Dil Thavarajah, 2021. Adapting Organic Lentil to the Southeastern US Climate and Soil. North American Pulse Improvement Association, Nov 2-4, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Tristan Lawrence, Dil Thavarajah, 2021. Going Organic Breeding organic dry pea cultivars. North American Pulse Improvement Association, Nov 2-4, 2021. - Type: Theses/Dissertations Status: Published Year Published: 2022 Citation: Nathan Johnson, LENTIL (LENS CULINARIS MEDIK.) PREBIOTIC CARBOHYDRATES AND PROTEIN QUALITY: UNCOVERING GENOMIC ASSOCIATIONS AND DEVELOPING RAPID FTIR PHENOTYPING METHODS, August 2022, Clemson University - Type: Websites Status: Awaiting Publication Year Published: 2022 Citation: Website: clemson.edu/cafls/organic-breeding/orei/ - Type: Websites Status: Published Year Published: 2022 Citation: YouTube Channel: Clemson Pulse Breedinghttps://www.youtube.com/channel/UCvfFSQSuo12_tNy7qZFATwg - Type: Other Status: Published Year Published: 2022 Citation: Twitter Handle: \@CpulsesBreeding https://twitter.com/Cpulsesbreeding - Type: Other Status: Published Year Published: 2021 Citation: Organic Pulse Breeding, Market Bulletin, SC Department of Agriculture, Vol 25, 10. - Type: Other Status: Published Year Published: 2021 Citation: Clemson doctoral student determines lentil genetic markers vital for global nutrition security. Clemson University. https://news.clemson.edu/clemson-doctoral-student-determines-lentil-genetic-markers-vital-for-global-nutrition-security/ - Type: Other Status: Published Year Published: 2021 Citation: Clemson research aims to help S.C. farmers meet the demand for more nutritious legumes https://news.clemson.edu/clemson-research-aims-to-help-s-c-farmers-meet-demand-for-more-nutritious-legumes/ - Type: Other Status: Published Year Published: 2021 Citation: Atlanta Business Journal https://atlantabusinessjournal.com/clemson-research-aims-to-help-sc-farmers-meet-demand-for-more-nutritious-legumes-agriculture/ - Type: Other Status: Published Year Published: 2021 Citation: The Times and Democrat - The \'poor man\'s meat\': Research aims to produce more nutritious legumes https://thetandd.com/business/agriculture/the-poor-mans-meat-research-aims-to-produce-more-nutritious-legumes/article_fabfd5de-311b-529f-8979-787422b412cd.html - Type: Other Status: Published Year Published: 2021 Citation: Florence Morning News https://scnow.com/agriculture/clemson-research-aims-to-help-sc-farmers-meet-demand-for-more-nutritious-legumes/article_821baf76-1ce6-11ec-ac47-3bdacfb13994.html - Type: Other Status: Published Year Published: 2021 Citation: Southeast Farm Press Daily email newsletter. https://enewspro.penton.com/preview/farmpress/SEFP-01/20210923_SEFP-01_75/display?utm_rid=CPG02000002564174&utm_campaign=61999&utm_medium=email&elq2=eebf46faba394f53b3d072ab587ddcdb - Type: Other Status: Published Year Published: 2021 Citation: Carolina Farm Steward Association https://us12.campaignarchive.com/?u=d23f69ef676d1fb458eadcd63&id=42d1cd7c4f&e=c5e879a6d2 - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Thavarajah Dil,

2021. Alternative proteins, Plant-Based Foods, and the City: From Seed to Take-Out. Invited Panel/presentation, New York Botanical Garden \"food dialogues\" program. NY, Oct 1, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Thavarajah Dil, 2021. Organic pulse biofortification program, Seminar, PES, Clemson University, SC, Oct 15, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Thavarajah Dil, 2021. Pulse Crops and Human Health, CU School of Health Research, Invited Seminar, Nov 4, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Thavarajah Dil, 2021. Pulse breeding towards N fixation (Part-2), Invited lecture PES 8900: Plant Nitrogen Metabolism, Nov 23, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Thavarajah Dil, 2021. Invited talk, Organic dry pea breeding for SC, Carolina Golden Rice Foundation, Nov 30, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Thavarajah Dil, 2022. Invited Panel Speaker, Plant-based protein - UNC CleanTech Summit, UNC, Chapel Hill, March 30, 2022. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Thavarajah Dil, 2022. Invited Speaker, Organic Pea Breeding, Upstate Vegetable Grower Meeting, Greenville, SC, April 11, 2022. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Thavarajah Dil, 2022. Speaker, OREI: Sustainable organic pulses, Organic pulse breeding team meeting, July 28, 2022. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Thavarajah Dil, 2021. Organic Pulse Breeding for Human Health, Invited Seminar, College of Agriculture, Animal Science and Veterinary Medicine (CAVM), Busogo Campus, University of Rwanda, Musanze, Rwanda. August 2, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Thavarajah Dil, 2021. Invited talk, Nutritional importance of lentil in fighting back malnutrition - experiences from a model work. Legume Systems Innovation Lab Event on Lentil Sector in Nepal, USAID Nepal, Dec 16, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Thavarajah Dil, 2022. Invited talk, Biofortification of pulses-recent Developments. Western Ag- Professional Development conference 2022, Saskatoon, Canada. March 2, 2022.

↑ Return to Index

Optimization of Cover Crop Selection and Carbon Waste Stream Recycling to Facilitate Anaerobic Soil Disinfestation in Southeastern Diversified Organic Vegetable Farms: a Planning Grant

Accession No.	1026695
Project No.	SC-2021-02940
Agency	NIFA SC.\
Project Type	OTHER GRANTS
Project Status	EXTENDED
Contract / Grant No.	2021-51300-34897
Proposal No.	2021-02940
Start Date	01 SEP 2021
Term Date	28 FEB 2023
Grant Amount	$50,000
Grant Year	2021
Investigator(s)	Cutulle, M.; Diaz-Perez, JU, C..; Zhao, XI, .; Narayanan, SR, .; Farmaha, BH, .; Zhang, LI, .; Branham, SA, E..; Ward, BR, .; Rainwater, AN, ON.

NON-TECHNICAL SUMMARY

The rationale behind this project is to develop a research/grower/produces/ extension team who will collaborate on the synthesis of a 2022 integrated OREI proposal focused on improving organic vegetable production in the southeast. As noted in the executive summary this project aligns with goal 1 of the farm bill \"Facilitating the development and improvement of organic agriculture production, breeding, and processing methods\". Specifically this project focus on priority number 5 for the FY 2020 areas to \"Explore technologies that meet the requirements of the National Organic Program (NOP1) and protect soil, water, and other natural resources. This includes developing, improving, and evaluating systems-based integrated management programs to address diseases, nematodes, weeds and insect pests-related problems for organically grown crops. \...\" The inclusion of economist Dr. Lisha Zhang on the proposal allows us to contribute to the goal of \"Evaluating the potential economic benefits of organic agricultural production and methods to producers, processors, and rural communities\". By investigating the availability of carbon waste streams and surveying the types of cover crops used on farm we hope to evaluate the potential of ASD for increasing vegetable yield in the southeast. Growers conducting on farm trials will be able to master the nuances of initiating ASD if an integrated proposal is funded in 2022.We will rely on the expertise of Dr. Lisha Zhang to facilitate on farm surveys of grower likelihood to adopt our proposed technologies. The Tobit model (Tobin 1958) will be used to analyze farmers\' willingness to adopt a new production practice (Adesina and Zinnah 1993, Nkonya, Schroeder, and Norman 1997, Nassimbeni 2001, Chiputwa, Langyintuo, and Wall 2010, Idrisa, Ogunbameru, and Madukwe 2012). In order to determine which factors affect whether farmers choose to adopt organic production methods for key southeastern vegetables, the percentage of acreage adopting organic methods will be constructed as the dependent variable, while other factors, such as farmers\' demographic variables (e.g., age, education level, income, years of farming), land (acres owned or leased), the availability of required facilities, and the prices of major inputs (e.g., germplasm, carbon sources, cover crops), will be constructed as the independent variables.

OBJECTIVES

Goal 5-Explore technologies that meet the requirements of the National Organic Program (NOP)1 and protect soil, water, and other natural resources. This includes developing, improving, and evaluating systems-based integrated management programs to address diseases, nematodes, weeds and insect pests-related problems for organically grown crops. Systems-based evaluations can include the safety and efficacy of allowable pest management materials and practices. Proposals addressing organic management of diseases, nematodes, weeds, and insect pests in the Southern Region are especially encouraged. Where possible, the projects should engage emerging technologies such as automation, remote sensing, artificial intelligence, and digital scouting to enhance plant protection and weed control as well as improve productivity. Legislative goal 5 is the main target for this planning proposal (80%). Optimizing anaerobic soil disinfestation (ASD) for control of soilborne pests in the southeast directly addresses this goal.Goal 9-Identify marketing, policy, and other socioeconomic barriers to the expansion of organic agriculture in the United States and develop strategies to address them. Lobbying and advocacy activities are not appropriate under this priority. The planning grant aims to target recycling of on farm carbon waste and cover crops, since cost of carbon sources has been a limitation to the adoption of ASD.

APPROACH

In order to apply the traditional ASD method, growers will have to spend more money up front on carbon sources, although less money will need to be spent on labor to hand-weed later on. Technically, growers\' willingness to pay (WTP) for carbon sources, the major input of the ASD method, should be equal to the amount of money saved as a result of using ASD. However, other factors, such as growers\' risk attitudes and environmental concerns, may cause the WTP to deviate above or below this predicted value. We will therefore use interval regression (Yang et al., 2011) to estimate other non-monetary factors that could possibly affect the WTP for the major inputs of the ASD method. Obviously, using on farm carbon waste to facilitate ASD will reduce the up-front costs that growers will have to invest. Further economic analysis will be conducted on the potential to use off site carbon waste streams (Such as canneries, vegetable processing facilities, etc.).Activities (September 1 2021-August 31 of 2022)Recruiting growers by email and phone will occur prior to September due date of the 2022 proposal being in January. Initial activities for this planning proposal will include visits to growers in order to sample cover crop material from their farm and recruit for on farm trials to be conducted in 2022 for the OREI integrated proposal. Concurrently, Dr. Cutulle and Mrs. Rainwater will visit processing facilities to recruit their participation in the 2022 fully integrated proposal. Information regarding processing waste output data from these facilities will be relayed to Dr. Zhang, who will be preparing economic analysis for the 2022 integrated OREI proposal. Mrs. Rainwater will also collect waste samples from the processing plants to analyze for carbon content (Table 1). In the Fall of 2021 seminars will be held in Alabama, Florida, Georgia, and South Carolina. This will be October through November of 2021. At these seminars Dr. Cutulle and the local Co-PD or collaborator will provide a tutorial to local growers regarding implementing ASD. Plans about recycling on farm carbon waste and using cover crops will be synthesized as well. Additionally, extension personnel, nematologists, plant pathologists, and bio-systems engineers will be invited to the seminars in order to recruit them for the 2022 integrated proposal. Extension personnel from Clemson, Auburn, University of Florida, University of Georgia as well as 1890\'s universities such as South Carolina State and Florida A&M will be recruited to increase the diversity of growers who can be included in the 2022 integrated proposal. A final planning meeting with the newly recruited growers, scientists, and advisory board members will occur in December to construct. Table 1. List of Cover Crops and Waste Streams That Will be Evaluated By Grower for Grace Contract Chemists. Summer cover crops will be sampled prior to September. On Farm Watermelon Culls Peach Waste (From Processing Plant) Sweetpotato Skins (Processing Plant) On Farm Blueberry Waste On Farm Citrus Waste or Processing Waste On Farm Night Shade Crop Waste Summer Cover Crop 1 (To be determined from survey/visits)Summer Cover Crop 2 (To be determined by survey/ visits)Winter Cover Crop 1 (To be determined by survey/visits)Winter Cover Crop 2 (To be determine by survey visits) Progress 09/01/21 to 02/28/23 Outputs Target Audience:The target audiences wasinclusive of diversified organicvegetable and small fruit growers as well as extension agents in Georgia, Florida and South CarolinaThese growers ranged in size and in organic certification status. With a couple growers havingmore than 1000 acres and some being smaller market gardners. We also targeted members of the plasticulture industry, whichincluded Charternext generation, Viaflex and Mosiac. Generators of carbon waste streams who were not interested in ASD themselves but a way to recycle their wastewere involved in the project as well. This included large growers, breweries, paper mills and processing/canning facilities. These groups were brought together at in person meetings in Charleston SC and in virtual meetings hosted by University of Florida, Universiy of Georgia and Clemson University. Changes/Problems:Dr. Lisha Zhang left Clemson University prior to the completion of the project. Dr. Dave Lamie was able to take over the economics portion of the planning grant. Dr. Lamie presented at multiple seminars assisting with economic questions from growers about ASD implementation. He also assisted in writing a full OREI proposal focused on ASD implementation. The transition from Dr. Zhang to Dr. Lamie went very smoothly. What opportunities for training and professional development has the project provided?Over 90 growers attended the seminars held at Clemson,

University of Georgia and University of Florida were introduced to the concept of ASD and how to implement it. Dave Lamie\'s economics lab conducted literature reviews on ASD and helped contribute to the full OREI proposal submitted this year \"Development of Strategies Optimizing Anaerobic Soil Disinfestation in Organic Horticultural Crops: A Prescription-Based Approach to Sustainably Manage Soilborne Diseases, Nematodes and Weeds\". Post-docs from Clemson attended the southern cover crops conference in Louisana to increase knowledge on cover crop implementation that will be beneficial for future studies using cover crops to facilitate ASD. How have the results been disseminated to communities of interest?This planning grant targed diversified organic growers in the southeastern US. The information was dissiminated through online seminars as well as 1 in person meeting. Members of the plastic mulch industry inclusive of Viaflex, CNG (Charter Next Generation) and Mosiac attended. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Four seminars were presented and 1 in person meeting was held with team members from this grant. At the seminars, different techniques were discussed for implementing ASD. This included cover crop termination techniques to optimize ASD, identifying local carbon waste streams and optimal strategies for selecting and applying plastic mulch.Over 90 indiviudals involved in growing specialtry crops attended the virtual seminars hosted by Clemson, University of Florida and University of Georgia. At the in person meeting, growers and members of industry were able to priortize needs that would be incorporated into a full OREI proposal. Dr. Cutulle also presented aspects from the planning grant at a virtual American Society of Horticultural Scientists (ASHS) seminarthat was hosted by the ASHS pest management working group. Publications **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: We have interacted through in person and virtual seminars with growers and extension agents from SC, GA and FL as well as companies involved in plasticulture in the southeast. Soil scientists, weed scientists, horticulturalists, a graduate student and plant physiologists from Clemson. Specifically, at UGA one research and one extension horticulturist, one extension plant pathologist, and one extension nematologist. At Florida 1 horticulturalist and 1 extension are helping prepare a seminar for Florida growers in October of 2022. The growers involvedin the seminars included small, medium and larger scale organic growers. Companies invovled in plasticulture (Charter Next Generation) and waste disposal (Ingevity) have expressed interest in the project as well. Changes/Problems: Dr. Zhang,the economist, has been replaced by Dr. Laime, who is also from Clemson University. Due to increases in covid we had to conduct two of the seminars in a virtual setting. What opportunities for training and professional development has the project provided? One in person seminar on cover crop optimization and ASD was conducted at Middleton Place in Charleston SC. This meeting included Plasticulture chemists, horticulturalists, weed scientists, plant physiologists, soil scientists, growers, extension agents, students and research organizations. A virtual seminar was conducted with growers, extension agents from Georgia as well as with economist (Dr. Laime). Overall, dozens of extension agents were introduced to the concept of ASD and how to implement it. How have the results been disseminated to communities of interest? We have conducted seminars in Georgia and South Carolina. Audience members included extension agents, researchers, growers. These growersincluded women and minority owners.. What do you plan to do during the next reporting period to accomplish the goals? We will host a virtual seminar with agents and growers from Florida in October of 2022. We will also analyze more carbon waste stream content from potential emerging sources. We hope to summarize some of the economic oppurtunites that some of the cover crops and carbon sources might provide in context with facilitating ASD. **Impacts** What was accomplished under these goals? We have conducted seminars in South Carolina and Georgia with one seminar being planned in Gainesville, Florida for October 14th 2022. We have also analyzed several agro-waste streams and cover crops for C and N content. These waste streams include corn silage, different cover crops and peach waste. We are attempting to hire a MS student to help with some of the economical analysis regarding ASD.

↑ Return to Index

Organic Confluences: Reducing Plastic Across the Organic Supply Chain

Accession No.	1026684
Project No.	DC.W-2021-02887
Agency	NIFA DC.W\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34891
Proposal No.	2021-02887
Start Date	01 SEP 2021
Term Date	31 AUG 2022
Grant Amount	$50,000
Grant Year	2021
Investigator(s)	Shade, J.; Maguire, KE, .
Performing Institution	ORGANIC CENTER FOR EDUCATION AND PROMOTION, 28 VERNON ST STE 413, BRATTLEBORO, VERMONT 05301

NON-TECHNICAL SUMMARY

Organic values are based on improving sustainability and reducing reliance on synthetic materials. However, synthetics such as plastics are used throughout the supply chain from the field to packaging. While there has been substantial interest within the organic community in finding alternatives to plastic, there has been a paucity of collaborative, sector-wide discussion around developing a strategy for reducing non-input synthetics such as plastics. This conference will fill that need by bringing together farmers, processors, distributors, retailers, researchers and policymakers to discuss challenges of plastic from the perspective of waste, climate change, and environmental/human health. The overuse of plastic in our society has led to serious environmental issues such as increasing fossil fuel use and greenhouse gas emissions, chemical leaching into soils and waterways, and poisoning of wildlife on land and in water. The United States is a major contributor of plastic waste;in 2016 the U.S. accounted for 4% of the global population, but it generated 17% of all plastic waste. Food production and distribution are major contributors to plastic waste. In the U.S. an estimated 816 million pounds of agricultural plastics are used with nursery containers making up more than half of plastic used, while horticultural film (e.g. mulch, row covers, and tunnels), irrigation tubing, livestock plastics, and pesticide containers following close behind. Plastic is also commonly used in the post-farmgate food pathway. Food packing is heavily plastic-based and accounts for over 40% of all plastic produced since the 1950\'s.The use of plastic has increased in the field as organic production has expanded, and COVID-19 has caused a further increase in plastic packaging in effort to minimize human contact. Additionally, recent research suggests that short-term relaxation on single-use food packaging during the COVID-19 pandemic may change consumer\'s behavior long-term. Our long-term goal is to increase the sustainability of organic production by reducing the use of plastic across the entire organic food chain. Our overall objective is to expand communication and collaboration across the diverse organic sector with policymakers and researchers at the table so that the industry can reimagine plastic use in organic production. To achieve these objectives, we will hold a hybrid format conference that combines in-person and remote participation together farmers, processors, distributors, retailers, researchers and policymakers to discuss challenges of plastic from the perspective of waste, climate change, and environmental/human health. The workshops will include case studies of innovative solutions to plastic use from the field to the table, and policy discussions to set the stage for the current global and national perspectives on plastic alternatives and UDSA National Organic Program allowances. The conference will conclude with break-out discussions to help build a roadmap that reimagines plastic use from field to table. We will publish the outcomes of the conference as a

white paper that highlights innovative plastic alternatives that are safe, NOP compliant, and available to the organic community. This white paper will also present policy recommendations and research needs to address incongruities between the needs of organic stakeholders for plastic alternatives and what is commercially available or feasible to use. We will also host a follow-up webinar to publicize the results from this conference and solicit feedback from a larger audience that may not have attended the conference. We expect the webinar to increase diverse, public engagement. The white paper and webinar will be available through eOrganic and The Organic Center websites. We are committed to engaging the next generation of farmers and researchers, and will actively reach out to young farmers and graduate students to participate.We expect thatour conference and outreach activitieswill facilitate the development and improvement of organic agricultural production by increasing the innovation and accessibility of plastic alternatives across the supply chain.

OBJECTIVES

Our long-term goal is to increase the sustainability of organic production by reducing the use of plastic across the entire organic food chain. Our overall objective is to expand communication and collaboration across the diverse organic sector with policymakers and researchers at the table so that the industry can reimagine plastic use in organic production. While our conference will focus on plastic use in general, our findings will help build the groundwork for future discussions around non-input use of synthetics in organic (e.g. bio-based mulches), and to this end we will include a strategy discussion around the role of organic regulations in addressing non-input synthetics (7 CFR §205.601).Specifically, this conference aims to:1) Discuss impacts of agricultural plastic use from the perspective of waste, climate change, and environmental/human health2) Discuss agronomic, processing, and distribution challenges that are currently addressed with plastics, and highlight innovative solutions to plastic use and waste from the field to the table3) Host policy updates and analyses to set the stage for the current state of plastic alternatives and UDSA National Organic Program allowances, and lay a framework for future discussions on non-input synthetic use4) Collaboratively build a roadmap that reimagines plastic use across the supply chainOur conference will facilitate the development and improvement of organic agricultural production by increasing the innovation and accessibility of plastic alternatives across the supply chain.

APPROACH

Based on past conference attendance, we expect the Organic Confluences Conference to bring together up to 200 participants including organic and transitioning farmers, plastic-alternative innovators, scientists, industry members, policymakers (particularly NOSB and NOP affiliates) and educators. We plan to use a hybrid format where we will host an in-person meeting that will be supplemented with a virtual, live participation option. This should expand participation when timing and travel is not feasible, particularly for farmer participation. We will also incorporate virtual presentations and pre-recorded videos into the program to expand our speaker pool, for those who are unable to join us in person. The conference will be held in conjunction with the Organic Trade Association (OTA) annual Organic Week in May 2022 (specific dates TBD), in Washington D.C. The OTA\'s Organic Week in Washington, D.C. draws over 500 organic stakeholders from small organic producers to major growers, family-run organic operations to nationwide companies, and researchers and policy advocates to distributors and retailers. The event was selected because it includes a wide range of stakeholder participants from across the organic sector. Holding the conference in Washington D.C. will also make it easier for policymakers to attend who are constrained by travel budgets. We will develop a program that is suitable for a hybrid in-person/virtual model, so that we can effectively engage a remote audience during live programming. This means that remote attendees will be able to ask questions during panel discussions and also participate in remote break-out sessions in conjunction with in-person break-out sessions. We expect that the hybrid model will allow the blossoming of ideas, conversations, and connections that come from in-person events, but also will allow those who are unable to travel for health, environmental, scheduling, or other reasons to attend and even speak at the event. The Organic Center has prior experience with virtual event planning and has hosted hybrid events such as our annual benefit dinner before the COVID-19 pandemic and will be capable of integrating this virtual and in-person event.The Confluences Conference will be highly interactive and facilitated by the PD, who has extensive facilitation experience with diverse groups. Programing will take a multifaceted approach to improve communication among organic farmers, handlers, researchers and NOSB/NOP. The 2-Day conference will include panels, lightning presentations, and roundtable discussions in the form of break-out sessions. Conference Day 1 will focus on how plastic is currently used to meet challenges faced by all organic stakeholders across the supply chain, obstacles and opportunities using bio-based and plastic-alternatives, consumer demand for plastic-alternatives, and how COVID-19 has increased plastic use, particularly in retail and food delivery. The environmental and human health impacts of plastic use in agriculture on global and local communities will be presented, followed by how novel alternatives to plastic measure up to current plastic-based strategies, and what

research is needed to move us toward reduced plastic use. This day will also include a panel that discusses plastic use in the context of national and international organic regulations and the future of non-input synthetics (like biodegradable plastic mulch) and plastic-alternatives in organic. This final panel session of the day will include the topic of equity and inclusion that addresses unequal access to cost-prohibitive bio-based and plastic-alternatives and discuss how to overcome this barrier. Conference Day 2 will focus on innovations in plastic-alternatives and utilize breakout and synthesis discussions to build a road map for the future. Specifically this day will host a 2-hr lightning session where stakeholders will share 5-minute presentations highlighting case studies where farmers, processors, and distributors have used novel alternatives to plastic, and the latest innovations from researchers working on plastic alternatives (evaluations from past TOC Confluences have shown that attendees find these lightning sessions that allow them to explore the pith of cutting-edge ideas useful and engaging). Conference participants then will break into small groups, (both in-person and virtually), to identify the biggest challenges and most prevalent solutions/paths forward to reinvent plastic use along the supply chain. The conference will end with a synthesis discussion that will develop recommendations for building a roadmap that reimagines plastic use across the supply chain. The conference will employ a Core Planning Team to take on the administrative tasks of conference planning, and an extended General Advisory Committee to help provide strategic guidance on the conference development. The Core Planning Team will be responsible for organizing the program, and will meet via conference call on a regular basis. The team will work with the advisory committee to set the agenda for all panel sessions, and to ensure that all invited speakers are ready to speak on topics that achieve the conference goal. The General Advisory Committee will provide input throughout the planning process, and will help identify current themes regarding impacts of plastics, plastic alternative needs and available solutions, assist in speaker recruitment, and disseminate outreach.Outreach plan: The Organic Center (PD Shade), USDA\'s Economic Research Service (Co-PI Maguire), eOrganic (Key Personnel Formiga), and the Organic Trae Association (Co-Investigator Mirenda), have strong connections with diverse stakeholder groups in the organic community. The conference will be promoted nationally, with outreach conducted by all four organizations including the eOrganic newsletter, and TOC and OTA e-mail list serve announcements, press releases, social media and newsletters. The event will also be promoted to grower groups, government agencies and academic researchers. These efforts will be made to draw as much of a diverse crowd as possible. Travel and virtual participation funds are budgeted to increase participation from farmers.The white paper and webinar will be available through eOrganic and The Organic Center websites. We are committed to engaging the next generation of farmers and researchers, and will actively reach out to young farmers and graduate students to participate. Progress 09/01/21 to 08/28/23 Outputs Target Audience:Conference planning, organization and execution engaged a diverse combination of educators, industry leaders, scientists, government staff/policymakers, farmers and artists. Because plastic touches all markets and all sectors at some point in the food and fiber supply chain, we were able to develop a conference that was aimed at all markets and sectors, and all food system stakeholders including consumers. We of course had a target of organic stakeholders, but were not exclusive. We also narrowed our scope to the food systems and therefore the fiber sector was less included than we would have preferred. JEDI- In order to comprehensively identify the ways in which plastic is used as important tools, define challenges assosciated with plastic reduction, and develop a roadmap solutions, we intentionally attempted to increase diversity and inclusion in our audience and speakers. We put significant effort into finding speakers that were not from the majority demographic and in the end out of 22 speakers we had: 5 BIPOC 12 Female Identifying 5 BIPOC-Female Identifying 8 farmers and Farmer representatives 1 Artist Farmer scholarships were open to all farmers, but we actively recruited farmers from BIPOC backgrounds and those that were economically and socially disadvantaged. We fundraised additional money from the industry in order to offer a total of 27 farmer scholarships. Of those 27, we had: 21 BIPOC 14 Female Identifying 11 BIPOC-Female Identifying The diversity of attendees was recognized by staff, new attendees and those who regularly attend confluences. This diversity was noted in a positive way in the formal evaluation of the event and also in comments shared throughout the event e.g. \"Hosting 27 scholarship participants is a huge win for our OTA community and the larger organic movement! These participants were thrilled to be invited and engaged in our event, and all other participants were excited to meet them and learn about their businesses and unique perspectives. These attendees help to spark new dialogues within the industry which will continue to help us reach new audiences and meet everyone\'s needs more equitably.\"-OTA staff member The partners who helped us identify farmers to bring with our scholarships were: National Latino Farmers and Ranchers Black Farmers Index Alabama A&M Small Farms Research Center National Young Farmers Coalition CCOF Georgia Organics Farmworker Association of Florida Kentucky Agriculture Development Advocacy University of District of Columbia We had a total of 150 people register for the conference event and 135 who attended. Speakers and their affiliations Session 1: What is the role of plastic in our food system? Cynthia Barstow, Protect Our Breasts / Sustainability Marketing UMass Isenberg School Dr. Lisa Erdle, 5Gyres Alejandra Warren, Plastic Free Future Dr. Dana Nettles, Dr. Nettles Natural Beauty Session 2: Use of Plastics in Organic Dr. Carol Miles, Washington State University Extension Dr. David Gonthier, University of Kentucky Camille Herrera, Driscoll\'s Renaud des Rosiers, Amy\'s (also Board Member, Biodegradable Products Institute) Dr. Kelly Nelson, USDA ERS and

Adjunct Professor, John Hopkins University Jason Cleaver, Columbia Basin Onion Session 3: Organic Regulations and Plastics Katherine DiMatteo, DiMatteo Consulting Chris Anderson, Sustainable Strategies - Advisors in Food & Agriculture Dr. Lisa Erdle, 5Gyres Kyla Smith, Pennsylvania Certified Organic (PCO) and NOSB Board member Session 4: The Future of Non-Input Synthetics, Recycling and Plastic-Alternatives Jazmine Mejia-Meunoz, California Marine Sanctuary Foundation Rhodes Yepsen, Biodegradable Products Institute Cynthia Minet, MFA, Moorpark College Mitch Ratcliffe, Earth911 Session 5: Innovations in Plastic Alternatives: Lightning Session Mike Dill, Organically Grown Company, Coordinator- Organic Produce Wholesalers Coalition Lindsey McCoy, Plaine Products John McKeon, Earthbound Farms Lisa de Lima, MOM\'s Organic Market Andrew Stephens, USDA- Foreign Ag Service Alejandra Warren, Plastic Free Future Advisory board members and affiliations Producers and Industry Joan & Drew Norman, One Straw Farm LLC, Maryland Javier Zamora, JSM Organics, California Perry Clutts, Pleasantview Farm, Ohio David Vetter, Grain Place Foods, Inc., Nebraska Dr. Dana Nettles, Dr. Nettles Natural Beauty, Alabama Megan Miller, Coconut Bliss Paul Schiefer, Amy\'s Kitchen Inc. Katie Clark, Happy Family / Danone Dr. Kaia Shivers, NYU/Black Farmers Index Amara Brown, Black Farmers Index Katherine DiMatteo, DiMatteo Consulting Mandy Makinen, National Co-op Grocers Researchers & Policy Houston Wilson, UC Organic Agriculture Institute Alexis Racelis, University of Texas Rio Grande, Center for Sustainable Agricultre and Rural Advancement Jane Sooby, California Certified Organic Farmers (CCOF) Kyla Smith, Pennsylvania Certified Organic (PCO) Jennifer Tucker, National Organic Program, USDA Lindsay Haines, USDA, NRCS Changes/Problems:1. We needed more funding As we began to develop the programming (after the workflow delay from COVID), we quickly realized that our original budget would not be enough to recruit the caliber and quantity of speakers we needed to cover such a broad topic. Perhaps in response to the changing economy, or perhaps there have been societal shifts in work-life balance since COVID, but whatever the reason, people, including academics who often cover their own expenses, were reluctant to travel and to present without all travel expenses covered, and many requested additional honorariums. We ran out of funds quickly just for speakers and needed still to provide scholarships to farmers. We were able to fundraise an additional \$80,000 cash and product donations (organic cotton tote bags) from industry sponsors. These donations largely helped us cover speaker fees and travel for 22 speakers, and 27 farmer scholarships. The funds also helped contribute more to the venue and AV expenses that were shared by our co-host organization, The Organic Trade Association. This helped ensure that we were able to select the best venue that was appropriate for our confluences. 2. We lost staff capacity and had a major leadership change which slowed progress on the programming. Changes in staffing significantly impacted the speed of our progress in developing the program and selected speakers. Nonetheless, we still were able to put together a very impactful and successful event. What opportunities for training and professional development has the project provided?Opportunities for professional development were made available to all conference speakers and attendees, especially those who were engaged in the breakout session and discussion. How have the results been disseminated to communities of interest? Social media Newsletters for TOC and OTA eOrganic report Sharing website in additional conversations/collaborations What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Goal 1) Discuss impacts of agricultural plastic use from the perspective of waste, climate change, and environmental/human health Major activities completed:Hosted a session titled \"How plastic moves through our food system and environment.\"This session showcased the role of plastic in our food system,how it can escape the supply chain and move through the environment and our bodies. Detrimental impacts of plastic pollution and exposure to plastic chemicals were highlighted, underscoring why we should care about reducing plastic along the organic supply chain and beyond. Key outcomes:A change in knowledge.Feedback from attendees was that this session was the most impactful session with many people saying they didn\'t know the extent of the problem of making and using plastic. The environmental justice presentation received the most positive feedback. Goal 2) Discuss agronomic, processing, and distribution challenges that are currently addressed with plastics, and highlight innovative solutions to plastic use and waste from the field to the table Major activities completed:Hosted the following sessions: \"Use of Plastics in Organic\" examined the use of plastics throughout the supply chain, highlighting challenges that organic stakeholders face that are currently addressed with plastic-based tools. \"The Future of Non-Input Synthetics, Recycling and Plastic-Alternatives in Organic\"explored the need for a future framework in discussions around non-input use of synthetic, recycling, and plastic alternatives in organic. \"Innovations in Plastic Alternatives.\"Rapid, 5-min. presentations highlighted case studieswherestakeholdershave used novel alternatives to plastic andoffer hopeful solutions for future plastic reduction 4) Key outcomes:A change in knowledge.Between the educational sessions and the breakout discussion, many people learned about a use for plastic that they may not have known about. Feedback from several attendees expressed their appreciation for having so many different kinds of stakeholders in the room to reduce silos and conversations that typically run in circles within their own groups. Goal 3) Host policy updates and analyses to set the stage for the current state of plastic alternatives and NOP allowances Major activities completed:Hosted a session titled \"Organic Regulations and Plastics: Policies, Pathways, and Challenges.\"This panel included updates from NOP regulators on the current status of plastic regulation in general and specifically for organic, and discussions about the complexities

of regulating plastic use in organic. Key outcomes:A change in knowledge. During this session, we heard from several elders in the industry who were actively participating in the community before, during, and after the Organic Production Act was developed and passed. They shared their experience with rulemaking and where plastic fell into these conversations. Many of the younger audience members did not know this history. Others were not aware of recent and upcoming potential changes in policies that conflict with plastic and plastic alternatives. Goal 4) Collaboratively build a roadmap that reimagines plastic use across the supply chain Major activities completed: We hosted a breakout session and discussion addressing the following questions: Data collected: 1. Does plastic provide any critical, additional tools that haven\'t been highlighted yet? Many uses of plastic from the field to the table were identified. 2. What are thebiggestchallenges you have faced or have witnessed in trying to reduce plastic in your area of the supply chain? Cost and feasibility of implementing substitutes Lack of research on the impacts of the substitutes (e.g. hidden effects of biodegradable plastic) Conflicts of substitute use and organic policy (e.g. biodegradables in organic compost disqualifying compost as organic compliant; no commercially available biodegradable mulch meets organic standards, SOE is increasing the need for tamper-evident plastic packaging to reduce potential of fraud) Substitutes do not as effectively fulfill the function of the plastic tool Innovation of substitutes is taking too long In some parts of the supply chain, there are concerns that non-plastic tools increase food safety risks Recycling options are much more limited than most people realize 3.What should the top research priorities be to help reduce plastic use? Broad recommendations for research development Large-scale, complete supply chain assessment of what plastic tools currently exist, where are there alternatives, what are the pros and cons to the alternatives, what are the human health and environmental impacts of the plastic tool and its alternative (as defined by current research). From this we can gauge knowledge gaps and identify low-hanging fruits where an easy substitution will make a big difference, and where harder solutions need a better roadmap to substitution identified. More diversified inputs (ideas) and experiences from farmers (small +bipoc) Cross-industry collaboration to set top priorities together More funding to support plastic reduction research (make this a priority for NIFA programs including AFRI, SCRI, not just organic funding programs) Better synced research and extension Topical research recommendations More research into safe substitutes Index of toxicity Hemp fiber as an alternative component of biodegradable products Organic weed and pest control to reduce reliance on plastic as effective control tool Assessment of recycle programs and opportunities for circular economy More research that links plastic use in the field and along the supply chain to toxins, public & environmental health, and opportunities for innovation Research on the effectiveness of substitutes for maintaining the integrity of products 4. What strategies should be taken at a high-level to reduce plastic? Public education to educateabout the plastic crisis (health impacts, environmental impacts, etc.) Highlight stories of those communities that are directly impacted and make companies accountable Use education and a positive approach of why it is a better choice vs fear mongering Disincentivize the creation of plastic by taxing plastic manufacturers, while using those funds to help remove/recycle plastics, and more importantly R&D of better alternative materials. Make companies take responsibility for their own pollution and plastic use- not shift responsibilities to consumer Optimize packaging vs. Product ratio (e.g. bigger package sizes in stores like quart versus pint clamshells etc.) Regulate where the functionality of plastic pros outweighs cons i.e. single use vs medical use Partnerships between like-minded partners to go to government together to share their experiences to push for policy change More recycling programs that are better, but more importantly, we need to reduce single-use which will require retailer involvement and consumer behavior changes Key outcomes:A change in knowledge. The breakout and discussion sessions allowed different sectors of the supply chain to learn about others\' experiences and needs and collaboratively set priorities and develop next steps to start making change. Other Accomplishments we would like to highlight are: 1. We reduced plastic at our event in the following ways: Name tags (printed on seed paper with metal pins) Tableware was either glass or made from plastic-free, compostable materials We organized for all our compostable waste to be picked up from the hotel by a local green waste management company We used linen-free tables reducing plastic from polyester fabric Reduced signage Digital program 2. We surveyed attendees and got an overwhelmingly positive response. Overall,97.4% learned something new (Strongly agree/Agree), 94.9% plan to share what they learned with others in their network (Strongly Agree/Agree), and66.7%plan to incorporate learnings into action changes within their organization. Publications **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: Conference planning and organization has engaged a diverse combination of educators, industry leaders and scientists. We have begun planning conversations with the co-host the Organic Trade Association and industry leaders and scientists from Nature's Path, Driscoll's, 5 Gyres, and California Marine Sanctuary Foundation. In the next couple of months we will begin concentrated planning efforts that will include targeted meetings with our advisory board, retailers, scientists and farmers which will help us formulate our conference programming. 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? We plan to finalize the conference agenda, identify speakers, finalize in-person event logistics, advertise and complete registration, and hold the conference. We also plan to report out to our audience about outcomes from the conference. **Impacts** What was

accomplished under these goals? We have begun conference program development to meet our conference aims. Specifically we have interviewed several professionals working across the supply chain who have touched on aspects of all proposed content. Though in this process we have identified the need to emphasize the topic area of plastic recycling versus composting and the infrastructural needs for these solutions to be successful. While our conference will facilitate the development and improvement of organic agricultural production by increasing the innovation and accessibility of plastic alternatives across the supply chain, our interviews to date indicate that we need to focus not just on plastic alternatives, but also in how to improve plastic recycling and reduction of plastic escape/loss from agricultural use.

↑ Return to Index

Feeding Seaweed to Organic Dairy Cows

Accession No.	1026727
Project No.	VTVT-0094CG
Agency	NIFA VT.\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-35226
Proposal No.	2021-02893
Start Date	01 SEP 2021
Term Date	31 AUG 2025
Grant Amount	$2,900,000
Grant Year	2021
Investigator(s)	Greenwood, S. L.; Conner, DA, S..; Brito, AN, .; Contosta, AL, R..; Price, NI, .; Archer, ST, .; Welsh, RI, .

NON-TECHNICAL SUMMARY

Feeding seaweed to cows is already common in the organic dairy industry, but currently only wild-harvested, dried, ground rockweed (Ascophyllum nodosum) is widely available. The organic aquaculture industry farms numerous different species and has the capacity to process the harvest to significantly impact its dietary quality. The objectives of this proposed program are to work with both the organic dairy industry and the organic aquaculture industry to further develop this collaboration while financially benefiting both markets in a sustainable manner. By working directly with stakeholders, we aim to 1) identify currently perceived benefits and drawbacks of dietary seaweed inclusion in US organic dairy herd diets, 2) characterize organic seaweeds already available in the US that could be scaled up for broad adoption, and assess the impact of different processing methods on the chemical profile of the seaweeds, 3) use in vitro and in vivo methods to quantify the impact of feeding different combinations of seaweed species/processing methods on organic dairy cow health performance, and land nutrient cycling, 4) validate the impacts of dietary seaweed and demonstrate effective use and management of this strategy in partnership with commercial organic dairies, 5) complete a supply chain analysis to identify the potential of this market, and 6) seamlessly intertwine stakeholder and public outreach activities to gain widespread adoption and support for these sustainable organic practices, while creating long-term educational materials that will be incorporated into academic curricula to fuel the passion and skillset development in the next generation of organic stakeholders and scientists.

OBJECTIVES

The goal of this project is to enhance organic dairy profitability by boosting milk productivity and animal health while improving land stewardship and nutrient cycling through evidence-based use of dietary organic seaweed feedstuffs. The use of dietary organic-certified seaweed to address our goal carries additional benefits for the organic industry through improved demand of organic seaweed industry products. The specific objectives are to: Engage organic dairy and seaweed industry stakeholders to identify the limitations and benefits of seaweed inclusion in organic dairy diets; Determine the benefits and drawback of organic seaweed feeding supplements at the animal, farm, and ecosystem scales; Validate and demonstrate the use of seaweed in commercial partner organic dairy farms; Assess the impacts of seaweed feeding on the organic supply chain via interviews with feed suppliers, seaweed producers, and others; and Create a broad outreach program that includes demonstration and education opportunities to a variety of audiences.

APPROACH

ACTIVITY 1: Stakeholder perceptions of organic seaweed supplements and in vitro evaluations of nutritional value. Activity 1.1: Farmer knowledge, understanding, acceptance, and extension. We will use in-person and phone interviews, surveys, and focus groups to measure organic farmer understanding and interest in seaweed technologies. We will interview \~10 early organic adopters of dietary seaweed supplements to quantify perceived and measured effects on dairy production. This first round of interviews will guide a subsequent focus group of 8-10 organic dairy farmers not using seaweed-based feed to elicit their input into designing more attractive seaweed feed technologies and systems in years 1 and 2; members for each cohort have already been identified. Survey results will be analyzed to identify attitudinal, socio-demographic, and farm structure variables associated with interest in the seaweed-based feeds. Activity 1.2: Formation of Advisory Panel. Based on the feedback and responses from Activity 1.1, we will form an advisory panel of 12 members. This panel will help in selecting research focus for Activities 1.3, 2.1 and 2.2, and will meet via video quarterly/ Activity 1.3: Evaluate nutritional profile and rumen impact of organic seaweed. Commercially available organic seaweed supplements will be utilized in a combination of in vitro and in vivo trials to assess dairy production responses and land impacts. Nutritional characterization of seaweed: Seaweed species or seaweed blends subjected to individual or combination processing methods will be selected and analyzed to determine both the nutritive value of the seaweeds and the impact of processing method on chemical profile. Cumulatively, these methods will be used to generate a thorough assessment of the nutritional value of each species/processing combination and indicate ranges and limitations (based on safety, availability, and anticipated performance impacts) for inclusion rates as feed supplements for further in vitro and in vivo experimentation. A subset of treatments will be selected for further analysis based on likely commercial adoption success, with particular consideration for post-harvest handling ease, large-scale processing feasibility, likely success in incorporating into dairy rations, and nutrient profile and quality. Impact of seaweed feedstuffs on rumen performance: The selected seaweed/processing combinations will undergo further in vitro assessment using continuous culture fermenters. Treatments will be compared using Latin square experiments. The impact of feeding seaweed using both a fresh forage-based diet (experiment 1) and a hay forage-based diet (experiment 2) will be completed to model the impacts when feeding during the summer grazing season and the winter (indoor) season, respectively. ACTIVITY 2: Impact of dietary seaweed on animal and farm system performance. In vitro assessment results from Activity 1 will be shared with the Advisory Panel, who will participate in a working group discussion to select 2 treatments for assessment in the in vivo experiments outlined in Activity 2. Activity 2.1: In vivo assessment of dietary seaweed on organic dairy performance during the grazing season. This will be an in-depth research trial performed using the certified organic commercial dairy herd during the summer while cows are grazing on pastures. The benefits and nutrient cycling of seaweed feed additives during each of the trials will be assessed. Activity 2.2: Impact of seaweed supplement on dairy performance during the winter season. We will repeat assessment of the selected seaweed/processing treatments used in Activity 2.1 during the winter, using certified organic dairy cows housed indoors and being fed a typical winter lactating cow diet. Activity 2.3: Assessment of manure impacts on land and natural resources. We will examine how seaweed feed supplements affect the soil-crop agroecosystem by establishing experimental plots in pastures, treating these plots with excreta from cows receiving seaweed supplements, and then evaluating the fate of N in the excreta. We will conduct these plot experiments during periods to align with the in vivo assessments of dietary seaweed supplements during the pasture and winter seasons (Activities 2.1 and 2.2, respectively). We will measure emissions of CH4, CO2, and N2O. We will use the amount of N accumulated in buried resin bags as a proxy for soil N leaching. DeNitrification-DeComposition (DNDC) modeling simulations will be tweaked by adjusting the C:N and quantity of supplemental feed and manures as they may change during experimental trials. Model simulations will then be updated using data gathered during in vivo trials to parameterize feed quantities and C:N chemistry, animal efficiency, quantity and C:N chemistry of outputs (CH4, urine, manure), and nutrient cycling associated with output deposition location and decomposition environment. Once parameterized, sensitivities for C and N nutrient flows will be evaluated, with a focus on interactions with water and consequences on N leaching and soil GHG emissions. ACTIVITY 3: Commercial partner farm validation of seaweed supplement use To validate the efficacy of dietary seaweed in a commercial setting, Wolfe\'s Neck Center and Hudson Carbon will implement the optimized diet choice based on results from Activities 1 & 2. Determination of the \"optimal choice\" will be based on input from the Advisory Panel (which also includes representation from both of these commercial farms, as described in Activity 1.2).After initial farms surveys, the \"optimal choice\" supplement will be included in the lactating cow diet being fed to milking cows on both farms, and will be continuously fed during the summer grazing period, and during a second period during the winter indoor period. The specific outreach activities being performed in collaboration with these commercial organic dairies, which includes real-time demonstration as well as workshops and training opportunities, is listed in Activity 5. ACTIVITY 4: Supply chain analysis. The analytical frames for supply chain analysis, focused specifically on the organic sector, will be transaction costs and the value chain. For outsourced seaweed, our analysis will explore mutually beneficial partnerships to supply organic seaweed into feed supply chains. We will examine both flow of product downstream and the flow of information (i.e., efficacy and

performance of product, affordability, end-user acceptance). We will conduct \~20 interviews of feed suppliers, seaweed producers and processors, and others in the feed supply chain, developed in part by snowball sampling. Interview questions will focus on perceived organic farmer acceptability; current procurement strategies; ease of certifying seaweed farms and processing facilities and incorporating seaweed into existing organic supply chains; willingness to form partnerships in the supply chain; and impacts of organic seaweed incorporation on feed supplier revenues (prices received and volumes sold), costs (how will organic seaweed\'s costs compare with other feed inputs it will be replacing), and profitability. ACTIVITY 5: Outreach plan and education. Activity 5.1: Information sharing activities. Industry stakeholders will be sharing information throughout the entire project at different capacities, including 1) as participants in on-farm seaweed feeding validation (outlined in Activity 3), 2) as demonstrators (through on-farm demonstration and open-source data sharing), and 3) as participants in workshops and meetings. Commercial farm partners will also serve as the public-facing demonstration farms. Activity 5.2: Targeted teaching opportunities. Additional teaching and training opportunities will be used expand to academic, and applied on-farm teaching opportunities (see Audience section for more details). Progress 09/01/23 to 08/31/24 Outputs Target Audience: Our target audience is local farmers, both on the research site farm and in the community who are potentially interested in the use of seaweed as a feed additive and changing management practices to mitigate GHG emissions and improve productivity. The projects provided are targeted towards organic dairy farmers and researchers Organic and conventional dairy farmers, academics, policy makers, industry representatives and extension personnel. Dairy grazing apprenticeship/Trainees Regional dairy farmers Extension providers and agricultural support organizations General public, including families with children Summer camp-aged kids, middle and elementary school groups Undergraduate students Policymakers, Academics, Advocacy Organizations. Dairy farmers, dairy farm nutritionists, dairy product producers, general public Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Four graduate students attended a project meeting and interacted with a variety of scientists involved in the project. Two graduate students trained in literature review, interview, survey and quantitative and qualitative data analysis. WNC research, farm staff, and apprentices attended the 2024 Northeast Grazing & Livestock Conference - Provided Lab Technicians with experience collecting green house gas flux data using a multiplexed static chamber system. (Daniel Kaufman, Jack Ryan, Tiffany Runge) The projects stated have led to professional development through conference attendance and improvement in the handling/use of dairy cattle for both graduate and undergraduate students. May-August 2024: Undergraduate NSF-REU student from UNE at Bigelow Laboratory - Training in on-farm methane measurements. How have the results been disseminated to communities of interest? 9.18.23, Tour with International Association of Milk Control Agencies, 35 attendees 9.19.23, Tour Maine Medical Center Residents, 40 attendees 9.20.23, Presentation at World Wildlife Fund Oceans2050 Event, 75 attendees 10.31.23, Field Trip, Yarmouth Middle School Program, 100 attendees 11.16.23, Presentation with Maine Association of GIS Users Conference, 50 attendees 1.18.24, Agroecological Research Meeting with the Trustees of Reservations, 15 attendees 5.24.24, Lewiston Middle School Field Trip, 125 attendees 6.4.24, Northeastern Association of State Departments of Agriculture Presentation, 50 attendees 8.13.24, WNC Pasture Walk, cohosted with UMaine Extension, estimated 15 attendees The dissemination of results have been primarily through conference attendance. General public: Podcast Maine Science Festival, 8th August 2023, Kevin Posman. https://www.youtube.com/watch?v=7MvRrl_LtS8 What do you plan to do during the next reporting period to accomplish the goals?we will continue UNH dairy research, and repliacte at Wolf\'s Neck we will continue farmer acceptability and supply chain analysis Impacts What was accomplished under these goals? Completed supply chain analysis of kelp to dairy farms Completed focus group interviews of organic and conventional dairy farmers in Vermont, Maine and New York. Organic farmers very knowledgeable about algae feed supplements and use them as a health prophylactic and treatment. Conventional farmers not knowledgeable about algae feed supplements. Implemented a national survey of organic dairy farmers to assess their knowledge and use of algae feed supplements- currently being analayzed. Organic farmers use algae feed supplements to control mastitis, reduce fly problems, increase mineral content of milk and provide micronutrients to dairy cows. Need research to validate these observations. Survey data will provide national view of why organic farmers use algae feed supplements. Blood hematological parameters were measured with non-esterified fatty acids (NEFA) and cortisol being of primary interest. Additionally, phenotypic and health measurements were taken to assess the health (Heart and respiration rate, as well as rectal temperature, and body weight) and production of the animal, respectively. Collected manure from organic dairy cows fed different amounts of seaweed supplements during winter of 2024. Manure will be added to soil collected from UNH Organic Dairy Research Farm in a controlled incubation experiment. Collected manure from organic dairy cows fed different amounts of seaweed supplements during summer of 2024. Added manure to pastures at the UNH Organic Dairy Research Farm and monitoring soil greenhouse gas flux and soil nutrient cycling response in situ. 1. a) Animal trial of feed additive, Miner Institute: August 2023: Seaweed feed additive generated at Bigelow Laboratory b). Data: Feed additive stability tests; Bromoform residuals in milk, related to methane production in 3 cows . d. i) bioactive stability in on-farm setting; ii) information on dosing of bioactive in relation to methane emissions. a) Utilizing Ascophyllum nodosum

supplemented 0, 170 and 340 g per day to assess the influence seaweed has on lipolytic characteristics of Jersey cows in a feed restriction setting - 2024 continued Data Collection to determine baseline emissions from a composted windrow manure management strategy. - N2O,CO2, and CH4 fluxes measured using static chamber system from composting manure wind row. - Bi - weekly Nitrogen (N) , Ammonium Nitrogen, Bulk Density ,Total Solids , Manure Carbon, C:N, Sulfur, and PH - 2D Area, 3D Area, Volume of Pile using drone DEMs - Processed Data from 2023 to determine emissions of composting windrow. c) A 3x3 replicated Latin square with 6 Jersey cows was used to achieve proper power. The inclusion of seaweed did not lower NEFA values compared with the control animals, nor were any phenotypic characteristics altered. We are currently working on additional blood parameters. Extension brochures and articles for the popular agriculture press under development. WNC has a robust outreach, education, and demonstration program on-site, we\'ve worked to incorporate key components of the partnership, field trials, and dairy\'s role in climate adaptation and mitigation into our programs, some examples include: - Lead on-farm tours/presentations: audiences included state and federal employees, agricultural industry professionals and researchers, farm extension service employees and the general public. - Incorporate curriculum around organic dairy management, methane emissions reductions, and the seaweed trials into our educational curriculum for school age children. - Farmer training programs: Dairy grazing apprentices learn all on-farm record-keeping tasks, tools, and technologies, participate in on-farm outreach and learning activities and will be trained to participate in feed trials. A) A study is being currently conducted to assess mineral bioavailability of Chondrus crispus in mid lactating Jersey cows. No data currently available and will be reported in the following report. Publications Type: Theses/Dissertations Status: Accepted Year Published: 2024 Citation: Moen, Autumn and Conner, David, \"Stakeholder Opinions of Seaweed Supplements for Dairy Cows\" (2024). Food Systems Master\'s Project Reports. 36. https://scholarworks.uvm.edu/fsmpr/36 Type: Journal Articles Status: Accepted Year Published: 2023 Citation: Tynan, M.K., M.C. Bryant, R. Welsh, and S. Greenwood. 2023. Preliminary findings of northeast organic and conventional dairy farmers\' perception of benefits and challenges in feeding algae Renewable Agriculture and Food Systems DOI: https://doi.org/10.1017/S1742170523000157 . Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: Nutritionists Perspectives on the Efficacy of Feeding Algae Feed Supplements to Dairy Cattle. Presented at the Annual Meeting of the Rural Sociological Society in Burlington, VT. Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: Welsh, R. M.K. Tynan, R. Fitzgerald, S. Greenwood, D. Conner, N. Price, C. Quigley and A. Moen. 2023. Dairy Nutritionists Perspectives on the Efficacy of Feeding Algae Feed Supplements to Dairy Cattle. Presented at the gphers in Denver, CO. Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: Sims, W., Omoruyi, G., Mulakala, B., Driemel, A., Snider, M., Brito, A., Greenwood, S. 2024. \"Fermentation and digestibility characteristics of Ascophyllum nodosum, Alaria esculenta, and an Alaria esculenta and Palmaria palmata blend in a continuous culture system.\" J. Dairy Sci. 107 (Suppl. 1): 282 (Abstr.) (N) Progress 09/01/22 to 08/31/23 Outputs Target Audience:Dairy grazing apprenticeship/Trainees Dairy farmers through our regional outreach network Dairy and livestock focused extension providers and organizations General public, including families with children Camp aged kids, middle and elementary school groups Undergraduate students. Policymakers Academics/Research/Advocacy Organizations. Supply chains actors (e.g., Feed suppliers. Algae processors) Changes/Problems:The original PI left and there was a change in PI. The research on cows moved to UNH and will begin soon. What opportunities for training and professional development has the project provided?Training: Craig Burnell and Brigid Carr: NIST conference particpation: Supporting the Standardization of Seaweed Measurements held on October 24, 2023. WNC Dairy Research Fellow and Dairy grazing apprentices (DGAs) participated in a pasture walk at Mayday Farm in July of 2023 to learn about dairy grazing management, and record-keeping. -WNC Dairy Manager and Research Collaborations Manager attended Stony field\'s Annual Producer day which includes presentation, networking. Graduate students learned to work with and analyze data of various types including quantitative survey data, qualitative interview data and content analysis of web sites and marketing materials. How have the results been disseminated to communities of interest?General public: Maine Science Podcast Episode 48: Kevin Posman. https://www.mainesciencefestival.org/post/maine-science-podcast-episode-48 Colby Applied Ecology Class Tour: 1\~10 undergraduate students, March 30th. 2023 RISD Landscape Architecture Graduate Group Pasture and Dairy Research Tour: 25 graduate students and faculty, July 29, 2023 Dairy Research Tour for Grazing Extension Service Providers with the New England Grazing Network: 10 grazing extension professionals, May 10th, 2023 Dairy Research Tour US Forest Service Staff Tour: 5 USDA federal employees UNH Agroforestry Group Dairy Research and Pasture Tour: 10 graduate students, May 17th, 2023 WNC Pasture Walk Series for farmers and grazing service providers: 10 farmers and Maine based service providers. July 7th, 2023 What do you plan to do during the next reporting period to accomplish the goals?Continue research on seaweed in organic dairy cattle Continue research on dairy farmer adoption Continue research on supply chain analysis Continue outreach efforts Impacts What was accomplished under these goals? Objective 1: \"Engage organic dairy and seaweed industry stakeholders to identify the limitations and benefits of seaweed inclusion in organic dairy diets\" Began planning and prep for 2024 feed trials including: -assembling the project team and beginning development of project plan, equipment inventory -Worked with OpenTEAM staff to conduct record-keeping

review at the Dairy and ensured all pre-trial data collection is ready to go before 2024 trials (including monthly Dairy One sampling, pasture record-keeping) Surveyed dairy nutritionists about the benefits and risks and general knowledge of seaweed supplements. Reviewed claims of firms marketing seaweed supplements against assessment of the claims from dairy nutritionists using. Interviewed feed suppliers and algae processors to understand supply chain opportunities and obstacles Objective2: \"Determine the benefits and drawbacks of organic seaweed feeding supplements at the animal, farm, and ecosystemscales\" Participation in NIST inter-laboratory assessment - biochemical composition of seaweeds: proximate analyses and phenolic compounds. 2. Investigation into ensiling approach for Saccharina latissima: natural vs. addition of lactobacillus, pH stability and biochemistry. 3. Investigation of approaches to generate anti-methanogenic bioactives using Saccharina latissima and different sources of organic acids. Contributed to a manuscript highlighting the greenhouse gas impacts of manure applied to soil from cows that received seaweed supplements. This experiment was conducted in vitro. Recruited and hired students to document the benefits and drawbacks of organic seaweed supplement through a series of in vivo experiments that are in the planning stage Objective 5: \"Create a broad outreach program that includes demonstration and education opportunities to a variety of audience\" Surveyed dairy nutritionists about the benefits and risks and general knowledge of seaweed supplements. Public on-farm demonstration and field days: -Lead 9 on-farm tours/workshops on the farm that included an overview of the dairy research and demonstration farm, and the past and upcoming seaweed feed trials. Tours included undergraduate students, graduate students, farm extension service employees and the general public. -Hosted 1 public workshop with partners in the seaweed industry in our Dig Deeper series, WNC staff presented on the upcoming seaweed trials. Program and Outreach material development: -Summer dairy research communications: Updated our website, developed content highlighting Dairy research activities and partnerships through this project. Farmer training programs: -WNC currently had 3 apprentices in 2023, apprentices learn all on-farm record-keeping tasks, tools, and technologies, participate in on-farm outreach and learning activities and will be trained to participate in feed trials Publications Type: Journal Articles Status: Submitted Year Published: 2023 Citation: Arndt, K.A., Reyes, D.C., Quigley, C., Brito, A.F., Price, N., and Contosta, A.R., submitted. Seaweed supplementation to organic dairy cows may reduce climate impact of manure in pasture soils during a laboratory incubation, Agriculture, Ecosystems, and Environment. Type: Journal Articles Status: Published Year Published: 2023 Citation: Tynan, M., Bryant, M., Welsh, R., & Greenwood, S. (2023). Preliminary findings of northeast organic and conventional dairy farmers\' perception of benefits and challenges in feeding algae. Renewable Agriculture and Food Systems, 38, E23. doi:10.1017/S1742170523000157 Type: Theses/Dissertations Status: Published Year Published: 2023 Citation: Tynan, M. WHY FEED SEAWEED? TACIT AND CODIFIED KNOWLEDGE NETWORKS IN THE DAIRY INDUSTRY. M.S. Thesis. Department of Nutrition and Food Studies, Syracuse University. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:In this first year of the project, much of our public output was focused on sharing news of the award and the goals of the project. As such, notice of the award and the goals were shared to and by several public news media outlets, with the primary target audience being the general public. Media coverage for this OREI project included the following: 1. WCAX segment: https://www.wcax.com/2021/10/06/uvm-study-tests-out-feeding-cows-with-seaweed/ 2. Seven Days' \"Daily 7\" newsletter:https://mailchi.mp/sevendaysvt/vermont-urges-schools-to-perform-covid-19-testsmontpelier-author-named-national-book-award-finalist?e=6a27ade968 3. Local 22/44:https://www.mychamplainvalley.com/news/what-can-seaweed-do-for-vermont-dairy-cows-uvm-researchers-will-find-out/ 4. Patch.com:https://patch.com/vermont/burlington-vt/uvm-studies-seaweed-cows-bba-private-security-extension 5. VermontBiz.com: https://vermontbiz.com/news/2021/september/29/feeding-seaweed-cows-boost-organic-dairy-profitability-and-sustainability 6. SwansonReed.com:https://www.swansonreed.com/uvm-to-research-seaweed-for-organic-dairy-cows 7. Vermont Public Radio S. L. Greenwood interview aired on radio morning of 10/18/2021 VPR article: <https://www.vermontpublic.org/vpr-news/2021-10-15/news-roundup-scott-administration-says-it-will-extend-motel-emergency-housing-program-again> Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?This project is supporting training and professional development of both undergraduate and graduate students. One MS student at Syracuse University is currently involved in the development and implementation of the focus group and survey work implemented in this project to understand producer perception and use of organic seaweed supplements. A second graduate student is completing his PhD at the University of Vermont, with in vitro and in vivo assessment of target seaweeds on organic dairy production and health as the focus of his PhD. To support these graduate student projects, undergraduate research students have been engaged in sample collection. 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?For the next reporting period, in vitro experimentation will conclude, leading to advisory-panel inclusive discussions and decisions to be made regarding best candidates for use in the upcoming in vivo trials. In vitro results will be used as guidance to develop and complete the first planned in vivo experiments for this program, whereby seaweed supplements will be assessed on a certfied organic dairy research farm (Organic Dairy Research Farm (ODRF), University of New Hampshire). Anin vivo animal trial led

by co-PIs Brito and Contosta will include 24 lactating Jersey cows assigned to treatments (n=8 per treatment) in a randomized block design. Two weeks of baseline measurements will be completed as a covariate period, and cows will subsequently be assigned to one of 3 treatments (control, seaweed product 1, or seaweed product 2) for a 10-week experimental period. In situ experiments examining how seaweed feed supplements affect the soil-crop agroecosystem will also be accomplished by establishing experimental plots in pastures at the ODRF, treating these plots with excreta from cows receiving seaweed supplements, and then evaluating the fate of N in the excreta. Supply chain analysis will also commence, whereCo-PI Conner (with co-PIs Welsh, and Price) will conduct \~20 interviews of feed suppliers, seaweed producers and processors, and others in the feed supply chain, developed in part by snowball sampling (asking early-adopter organic farmers and interviewees for names of suppliers) and guidance from consultant R Kersbergen. Interview questions will focus on perceived organic farmer acceptability; current procurement strategies; ease of certifying seaweed farms and processing facilities and incorporating seaweed into existing organic supply chains; willingness to form partnerships in the supply chain; and impacts of organic seaweed incorporation on feed supplier revenues (prices received and volumes sold), costs (how will organic seaweed's costs compare with other feed inputs it will be replacing), and profitability. **Impacts** What was accomplished under these goals? In the first year of the project, we have worked toward addressing goals 1 and 2 of the program: 1. To engage organic dairy and seaweed industry stakeholders, Co-PI R. Welsh held focus groups and individual interview sessions during the winter of 2021. Led by co-PI Welsh, researchers held two focus groups in New York State and Maine with 17 organic dairy farmers and interviewed two Vermont organic dairy farmers via Zoom to discern their knowledge and use of algae-based feed supplements to obtain beneficial outcomes in herd health and productivity. Most interviewed farmers either use or had used such supplements to treat acute health issues in their cows or as probiotics or prophylactics. They believe the supplements are effective for improving herd health based primarily on their observations. Based on these results, the research team focused on identifying and assessing seaweed use in dairy diets has ensured focus on species that will address specific herd health issues identified by the stakeholders as requiring more attention. 2\. To determine the benefits and drawbacks of organic seaweed as a dietary supplement for use on organic dairy systems, we are currently completing in vitro characterizations and assessments of several candidate seaweed species. Bigelow Laboratory for Ocean Sciences is currently completing batch culture in vitro assessment of processed S. Latissima for use in certified organic systems. This seaweed species is a scalable and sustainable option for the US Northeast organic seaweed producers. Additional seaweed species and processing options for organic certified operations are being discussed with local stakeholders involved in the commercial organic seaweed market. Additionally, continuous culture fermenters are being used at the University of Vermont to assess combinations of certified organic Palmaria palmata and Alaria esculenta as potential seaweeds used asindependent supplements or mixtures for use in certified organic dairy cow diets.
Publications

↑ Return to Index

Advancing Organic Agriculture in the Mid-south: Evaluating Systems and Reducing Barriers to Entry

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Performing Institution	WINROCK INTERNATIONAL INST. FOR AGRIC. DEVELOPMENT, 1621 NORTH KENT STREET, SUITE 1200, ARLINGTON, VIRGINIA 22209

NON-TECHNICAL SUMMARY

Advancing Organic Agriculture in the Mid-South: Evaluating Systems and Reducing Barriers to Entry. Despite the overall rapid increase in organic crop production (OCP) in the U.S., the Mid-South region has seen only nominal growth in organic acreage and production. The primary reason is the lack of geographically-specific resources available to growers to help overcome production barriers. The most significant barriers include uncertainty regarding the perceived complexity involved with organic crop management, pest control concerns, and issues related to organic certification. In southern regions, climatic conditions, including a longer growing season, higher moisture, and warmer temperatures, add to the existing challenges in managing complex cropping systems. Yet, relevant organic production information is sparse. Farmers have justifiable concerns about organic systems with limited control options. The often-abstruse nature of the certification process creates an additional impediment to OCP. Geographically-relevant research and outreach efforts are needed to address these problems and make OCP more feasible for producers. This project addresses these issues by: 1) conducting a replicated, controlled field trial study on management of cover crops, tillage, integration of livestock, and effects on pests, soil health, crop yield, and economic feasibility; 2) establishing larger, on-farm, multi-state field demonstration trials to evaluate applied practices; and 3) providing outreach and education programs for producers and agriculture-related organizations on research-supported information, economic analysis of OCP systems, and the overall potential for organic production in the Mid-South region. This project will address the OREI goals of developing organic production methods, evaluating benefits to producers and communities, conducting advanced on-farm research, and examining optimal outcomes of organic production.

OBJECTIVES

The long-term goal of the project is to make organic farming a viable option for Mid-South farmers through production information that is tailored to the growing environment and support that is readily available through a community of practice. This will entail collecting and sharing high-quality research-based information demonstrating practical application of organic management production in the Mid-South region by accomplishing

the following three objectives: Objective 1: Conduct replicated research trials on organic crop management approaches This objective is to determine optimal organic crop management strategies, through one site of randomized, replicated research plots over three crop seasons. The replicated, small plot field trials will focus on organic crop management strategies including the use of cover crops, integration of livestock, and tillage for the management of crop residues, pests (weed and insect), disease, and improved soil health. This effort will involve establishing small (0.5 ac) plots in a randomized complete block, one factor design. Each management system will serve as a treatment with four treatments in total replicated four times for a total of 16 experimental units. The four primary crop management systems we propose are: conservation management, integrated enterprise (crop and livestock) with or without tillage, or profit driven. The no-tillage treatment will eliminate tillage altogether and the conventional tillage will consist of multiple tillage operations (disc, rototill) on an as-needed basis for weed management. Management systems The three-year rotation will consist of a soybean (commodity)-corn (commodity)-specialty soybean (food grade, i.e., edamame) rotation with different approaches to cover crop use and termination strategies (see below). The conservation management and integrated enterprise systems will require cover crops within each phase of the rotation, while the profit-driven approach will maximize the number of harvested crops per growing-season. Measured Parameters Crop yield and forage production and quality evaluations. At grain maturity, yield estimates will be calculated. Harvested grain will be tested for moisture, dried, cleaned and threshed as appropriate for each crop. In addition, harvest index (ratio of grain production to total aboveground biomass production) will be estimated. Pests and disease. Residue and weed cover and weed density will be estimated twice each growing season from four 0.25 m2 quadrats within each plot. Diseases will be monitored by scouting plots beginning at emergence, and once every three weeks until maturity. Insect problems will be monitored for all crop rotations and are expected to vary greatly depending on the crop, management system and year-to-year variation, with frequency depending on severity. Soil health evaluations. Baseline soil samples will be taken the fall prior to planting (on a per plot basis). Sampling will be repeated at the termination of the study to evaluate changes (using delta values; n=32 total) to soil physical, chemical, and biological properties. Economic evaluation. A partial budgeting approach - where revenue and cost differences across production systems are tracked - will be used to determine the most profitable system. Ownership charges for equipment will be estimated using either custom rates or typical equipment employed. Estimations for cattle performance in systems in which cover crops and crop residues are grazed will be estimated from forage quality. Sensitivity analysis will be conducted to assess the price premium needed to break even. Statistical analyses. Replicated plot work at DBSFRC will be analyzed as a randomized complete block, one factor design using PROC GLIMMIX in SAS. The response variables will be crop yield, weed density, weed cover, weed biomass, disease and insect incidence, disease and insect severity, forage production and nutritive value, and soil health (physical, chemical, and biological). Fixed effects will include the one main effect (management system), with block and year considered as random effects. Weed composition and cover, forage yield, and pest pressure will be analyzed as a repeated measure. Optimizing organic management through soil mapping. Digital soil mapping will be used to evaluate crop selections in this trial. Soil functional zones will be developed in the study areas through digital soil mapping principles where soil-landscape-water interaction combinations determine the optimum environment for different crop species. The digital soil mapping platform is scalable to larger regions and works from existing open-source information from the USDA Soil Survey (SSURGo) data layers and a digital elevation model (DEM) available from USGS. Objective 2: Implement geographically diverse, farm-scale trials to substantiate best management practices observed from Objective 1. This objective will replicate, at field-scale, research approaches evaluated in the replicated field plot research described in Objective 1, at three sites in three states (Arkansas, Missouri, Tennessee), using 20-acre plots to demonstrate management systems and record operations, over three cropping seasons. Economic analysis of farm-scale trials. Farm-scale trials will be used to obtain estimates of profitability of a subset of production practices evaluated at the research scale. Profitability assessment will require collection of data to determine revenue and expenses. Equipment use, time and fuel as well as all applied inputs will be tracked. Sensitivity analyses will be performed to again determine breakeven yield and price as with the research trials. Objective 3: Perform education and outreach activities to enhance producer adoption of organic production practicesThis objective will engage farmers in the target who are interested in organic production, guide 15 farmers through the organic certification process, disseminate research findings, and provide access to organic production information and support, over four years of the project.This objective is designed to 1) increase the number of farmers exposed to pertinent research-based information on organic crop production; 2) engage Extension Services, universities, industry and other organizations that can support the efforts and share information; and 3) increase the number of farmers transitioning to organic production with USDA organic farm certification.Disseminate information. Data and findings will be distributed to Extension Services, federal and state agencies, farmer cooperatives, commodity groups, research universities, etc. Site visits, conference calls, field days, public relations events, social media platforms will be used to share information. The project will provide: 1) monthly updates on research, 2) quarterly updates on producer demonstrations, and 3) coverage of field events as outlined in the schedule of the overall project. The project will target up to 15 potential organic farmers across the project.Field Days. The project will

hold a total of six field days over the course of the project at DBSFRC and the farm-scale trial sites if pandemic conditions allow, or shift to video conference meetings. Co-PIs will demonstrate the practices of field preparation, planting, in-season pest and fertility issues, cover crop use, residue management and other key practices. Farmer participation will be documented. Printed information will be distributed to attendees.?Organic Praxis WorkshopsWorkshops for farmers will be held comprising 1) research data / production practices, 2) organic commodity markets and sales, and 3) orientation to USDA organic certification. Two workshops will be held (in winter) over the life of the project.

APPROACH

The 48-month project will consist of replicated small plot research; geographically diverse farm-scale trials; and targeted outreach and education to demonstrate the viability organic production systems in the Mid-South region. Project implementation will be coordinated as follows: Winrock will be the prime grant applicant, general project manager, and fiscal agent.The USDA-Agricultural Research Service will lead the replicated field research work, digital soil mapping, research data collection, analysis, advising farm-scale site design and management, and contribute to education, outreach, and project reporting. The Natural Soybean and Grain Alliance will lead coordination and support for the farm-scale trial sites, lead education and outreach efforts, and collect data. The University of Arkansas at Fayetteville (UARK) will lead the economic analysis of organic cropping systems, collect and analyze data, and produce reports. 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The project will provide: 1) monthly updates on research, 2) quarterly updates on producer demonstrations, and 3) coverage of field events as outlined in the schedule of the overall project. The project will target up to 15 potential organic farmers across the project.The project will hold a total of six field days over the course of the project at DBSFRC and the farm-scale trial sites if pandemic conditions allow, or shift to video conference meetings. Co-PIs will demonstrate the practices of field preparation, planting, in-season pest and fertility issues, cover crop use, residue management and other key practices. Farmer participation will be documented. Printed information will be distributed to attendees.Workshops for farmers will be held comprising 1) research data / production practices, 2) organic commodity markets and sales, and 3) orientation to USDA organic certification. Two workshops will be held (in winter) over the life of the project. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Information was distributed via telephone, in-person meetings, \"X\" social media (formerly Twitter), web pages, podcasts, and E-mail to interested parties in the project region. Project information was shared with producers in the project area who operate various sizes and types of farm enterprises. Information was sent to agencies and organizations in the farming sector, such as university systems, University Extension Service, the Arkansas Department of Agriculture, USDA local offices, commodity boards, etc. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Four staff members of the USDA ARS Dale Bumpers Small Farms Research Center (project partner) attended the 2024 American Forage and Grassland Council annual convention, where they presented project information and increased their expertise in cover crops and forage production. The Director of the Natural Soybean and Grain Alliance (project partner) attended and presented at the Annual Arkansas Grown Conference and Expo in January 2024. There, he discussed the overall project, including progress made and barriers encountered, and took questions in a discussion segment at the end of the presentation. How have the results been disseminated to communities of interest?Project information, photos, reports, and videos have been loaded on a public website for the project. This site and its information have been shared with farmers and Extension Service contacts directly via E-mail, as well as being promoted via X (formerly Twitter) social media accounts (e.g. \@winrockorganic). The project created a series of podcasts to feature activities and organic production topics. The project collaborated with the University of Arkansas TOPP (Transition to Organic Partnership Program) to develop podcasts which addressed these topics: 1) a project overview and organic farming agronomics (April); 2) general economics of organic farming (June); and 3) input costs and profitability of organic farming (August). A fourth podcast is planned, covering USDA organic certification, for later in the year. A field day/youth career day was held on September 19, 2024, at the Missouri demonstration site, where approximately 1,600 agricultural students and professionals attended the event. The project\'s organic plot was part of a tour, along with a discussion of local agricultural activities. What do you plan to do during the next reporting period to accomplish the goals?Activities in the final year of the project will shift to data analysis, economic modeling, and reporting, as field work at the research and demonstration sites has been completed. The project team will review the project outcomes and develop recommendations as relevant. Information will be shared on websites, social media, and shared directly with farmers and the agriculture community. Impacts What was accomplished under these goals? Impact The project\'s goal is to make organic farming a viable option by providing production information tailored to conditions in the Mid-South. In its third year, the project continued implementing research and demonstration sites as planned. Results suggest that the most beneficial practices are establishing selected winter cover crops early for maximum fall growth, while the timing of planting summer crops may be more beneficial at later dates, and timely cultivation enhances weed control. Conditions observed at demonstration plots in three states reinforce these conclusions. Objective 1: Conduct replicated research trials on organic crop management approaches 1) Major activities completed / experiments conducted: Replicated research plots comparing four management systems continued. Plots were planted with a cereal rye cover crop in fall 2023, and the 2024 summer crop was soybeans. In the conservation system (no-till), the cover crop was roller crimped, and soybeans planted. In the integrated system (with livestock) calves grazed both no-till and tilled plots followed by soybean planting. In the profit-driven system (conventional tillage) soybeans were planted after cereal rye was harvested. 2) Data collected: Data collected included cover crop biomass, grazing time, cattle

weight gain, seeding rates, stand counts, weed types and counts, and crop yields. Multiple weed species were identified and recorded. Digital soil mapping was completed across all project sites, and information was shared with project partners. 3) Summary statistics and discussion of results: The cover crop, grazing, and tillage worked well. The research plots had weed pressure in the summer crop, with differences observed between treatments. In the conservation plots, moderate cover crop growth was challenged by established plant species. In the integrated system, summer crop growth was reasonable. In the profit-driven system, cereal rye produced much biomass which benefited weed suppression. Economic analysis is being conducted on cropping system input costs and yields/income to determine potential profitability. 4) Key outcomes or other accomplishments realized: Data and observations suggest practical lessons for organic management: Early fall planting of the cover crop is important to establish a stand that will provide an adequate biomass mat. Spring grazing is valuable for cattle weight gain but grazing too long (prior to crop planting) can give weeds an advantage over the summer crop. In seasons 1 and 2 early summer crop planting was pursued, but in season 3 plots that were planted later performed better and weed management was reasonable. The advantage of later planting was not anticipated and may be clearer in further study. Consistent and timely inter-row cultivation helps control weeds and allow reasonable crop growth. No-till plots require a high level of management. We continue to learn the nuances of how to establish a cover crop, and these approaches may be distinctly different than those that work well in tilled treatments. Objective 2: Implement geographically diverse, farm-scale trials to substantiate best management practices observed from Objective 1 1) Major activities completed / experiments conducted: The project established three demonstration plots in year one, and these were continued through growing seasons two and three; no plots received irrigation. In year three, the Arkansas and Tennessee sites used the conservation (no-till) and profit-driven (conventional tillage) systems. Cereal rye was the cover crop, and the summer crop was soybeans. Biomass production was good at the Arkansas site. Crop production had variable results, performing better under tillage, generally. Wildlife pressure has been an unanticipated challenge during the project, and we have explored various control measures. The Missouri site used the integrated system and a cereal rye/clover cover crop, with grazing on both conventional and no-till plots. After grazing, soybean plots were planted. Timely rains and tillage resulted in reasonably good grain production in the field. Overall, the tilled plots appeared comparable to soybean crops produced in nearby areas. The no-till plots illustrated the need for unique approaches to establishing cover crops and managing the summer crop. 2) Data collected: Crop data collected included cover crop biomass, grazing time, cattle weight gain, planting rates, seeding rates, stand counts, weed types and counts, systems input costs, and crop yields. Digital soil mapping was expanded beyond the research plots to include the demonstration sites in Missouri and Tennessee. 3) Summary statistics and discussion of results: Cover crop establishment was generally good, with some weather-related challenges. The Missouri site\'s conventional tilled plots performed well, continuing the pattern of exceeding the no-till plots. At the Arkansas site, an edamame crop was planted as the demonstration and grew well with adequate moisture. Harvest samples averaged about 12,000 lbs./acre with good quality. 4) Key outcomes or other accomplishments realized: At some sites, good summer weather contributed to successful summer crop production in the conventional tilled plots. At sites with poor weather conditions, the need for attention to early crop planting and timely cultivation were reinforced as important management tools. Irrigation and cultivation may mitigate problems if timely planting and good weather are not realized. Objective 3: Perform education and outreach activities to enhance producer adoption of organic production practices 1) Major activities completed / experiments conducted: A field day event was held on August 4th, 2023, at the Missouri demonstration site. Approximately 15 farmers attended the plot tour, where information was shared about the project and demonstrated successful organic corn and sorghum production. A tour at the Missouri site was conducted on August 28, 2023, and attended by U.S. Representative Eric Burleson, the Dean of Missouri State University, regional farmers, professors, and executives in ag sector organizations. A career and exploration day was held at the Missouri site on September 21, 2023, where the project and demonstration plots were presented and discussed to hundreds of agricultural students from throughout southwest Missouri. A public meeting of project partners was held on February 28, 2024, with presentations on progress, markets, economics, and discussion of project plans for the coming year. A public website is hosted by Winrock International featuring project information, reports, photos, and related content. A series of podcasts were produced, in collaboration with the University of Arkansas and the TOPP program, featuring project activities and general information on organic farming and the transition process. Numerous social media items were posted with web links and general project information. 2) Data collected: The project recorded names and contact information of farmers who attended events and are interested in organic production. 3) Summary statistics and discussion of results: n/a 4) Key outcomes or other accomplishments realized: The project generated information from its research and demonstration plots that was shared with the public through a spring organic farming meeting and demonstration site field days. Other dissemination took place through podcasts, social media, websites, and through virtual and in-person meetings. ?Organic Praxis Workshops A public meeting promoting organic production, titled Organics in the Ozarks, was held April 12, 2024, organized by project partner University of Missouri in coordination with the Missouri Organic Association. Over fifty people attended, including many local farmers. Presentations included weed management, transitioning

to organic, TOPP program reports, irrigation design, fertility management, etc. Publications Progress 09/01/22 to 08/31/23 Outputs Target Audience:Information was distributed via telephone, in-person meetings, Twitter, web pages, and E-mail to interested parties in the project region. Project information was shared with producers in the project area who operate various sizes and types of enterprises. Information was sent to agencies and organizations in the ag sector, such as university systems, Co-operative Extension Services, the Arkansas Department of Agriculture, USDA local offices, commodity boards, and over 20 direct recipients. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Staff at the University of Missouri Southwest Research, Extension and Education Center (project partners) have increased their skills with organic crop production in traditional livestock productions systems. How have the results been disseminated to communities of interest?Project information, photos, reports, and videos have been loaded on a public website for the project. This site and its information have been shared with farmers and Extension Service contacts directly via E-mail, as well as being promoted widely via a Twitter account. A mid-project report was published, describing work from fall 2021 to summer 2023. The report was E-mailed to public agencies, such as universities, the Natural Resources Conservation Service, Co-operative Extension Services, USDA office in Arkansas, the Agriculture Department of Arkansas, commodity groups, the Ag Council, etc. The report was posted on websites, linked on social media, and shared in meetings. A field day/youth career day was held on September 21, 2023, at the Missouri demonstration site, where over 2,000 students and ag professionals attended the event. The project\'s organic plot was part of a tour and discussion of local ag activities. What do you plan to do during the next reporting period to accomplish the goals?Activities at the research and demo sites will continue as planned. Based on information generated to date, the project will continue to refine management practices to meet the challenges of organic production. Another public meeting to share results is being planned for winter 2024, and more field days are being planned for summer 2024. The project will collaborate with a local organic association to host a farmer information meeting in early 2024. The project will coordinate efforts with the local implementation of a USDA Transition to Organic Production Program project. Impacts What was accomplished under these goals? Impact The project\'s goal is to make organic farming a viable option by providing production information tailored to conditions in the Mid-South. In its second year, the project continued implementing research and demonstration sites as planned. Results suggest that the most beneficial practices are establishing selected winter cover crops early for maximum fall growth, establishing summer crops earlier in the spring to compete with weeds, and timely cultivation. These conclusions were observed at demonstration plots in four states, and consistent from year one to year two. Objective 1: Conduct replicated research trials on organic crop management approaches 1) Major activities completed / experiments conducted: Replicated research plots comparing four management systems continued. Plots were planted with a winter wheat cover crop in fall 2022, and the 2023 summer crop was sorghum. In the conservation system (no-till), the cover crop was roller crimped and sorghum planted. In the integrated system, calves grazed both no-till and tilled plots followed by sorghum planting. In the profit-driven system (conventional tillage) sorghum was planted after winter wheat harvest. 2) Data collected: Data collected included cover crop biomass, grazing time, cattle weight gain, seeding rates, stand counts, weed types and counts, and crop yields. Insects and pests were negligible. Multiple weed species were identified and recorded. 3) Summary statistics and discussion of results: The cover crop, grazing, and tillage worked well. The research plots had much weed pressure in the summer crop, therefore, small sub plots were hand weeded. Differences were observed between treatments. In the conservation plots, a thin cover crop stand led to minimal weed suppression. In the integrated system, summer crop growth was reasonable. In the profit-driven system, winter wheat harvest yielded \~36 bu/ac. Economic analysis (from fall 2022 data) of the systems suggests that a break-even yield for organic production is lower than a comparable crop under conventional systems. While drought stress also impacted conventional fields, less droughty conditions may yield higher in conventional systems. 4) Key outcomes or other accomplishments realized: Data and observations suggest practical lessons for organic management: Early fall planting of the cover crop is important to establish a stand that will provide an adequate biomass mat after crimping. Spring grazing is valuable for weight gain but grazing too long (prior to crop planting) can allow weeds to outgrow the summer crop. Earlier summer crop planting dates and higher seeding rates allow the crop to compete with weeds. Consistent and timely cultivation helps to control weeds and allow reasonable crop growth. No-till plots require a high level of management skill and attention to manage weed pressure. In drought conditions with complete yield loss, companion grazing and/or haying offer ways to diversify for positive cashflow. Objective 2: Implement geographically diverse, farm-scale trials to substantiate best management practices observed from Objective 1 1) Major activities completed / experiments conducted: The project established three demonstration plots in the first year, and a fourth site (Oklahoma) in year two. No plots received irrigation. The Arkansas, Tennessee, and Oklahoma sites used the conservation (no-till) and profit-driven (conventional tillage) systems. Winter wheat was the cover crop. Weather conditions reduced wheat biomass production. The summer crop was corn. Success was mixed, and the corn performed better under tillage. The Missouri site used the integrated system and a cereal rye cover crop, with grazing on both conventional and no-till plots. After grazing, side by side plots of corn and sorghum were planted. Timely rains and tillage resulted in good yield for both crops. The no-till

plots failed due to thinner stands and heavy weed pressure. 2) Data collected: Crop data collected included cover crop biomass, grazing time, cattle weight gain, planting rates, seeding rates, stand counts, weed types and counts, and crop yields. 3) Summary statistics and discussion of results: Cover crop establishment was good at all sites. The TN site had much winter kill, and rain prevented corn planting. The MO site conventional tilled plots performed well, but no till plots failed due to weed pressure. At the AR site, crop stands were good in the conventional tilled plot, but the no till plot failed due to thin stands and weed pressure. At the OK site, early season growth was good, but weed pressure overtook the plot. 4) Key outcomes or other accomplishments realized: At some sites, good summer weather contributed to successful summer crop production in the conventional tilled plots. At sites with poor weather conditions, the need for attention to early crop planting and timely cultivation was apparent. Irrigation and cultivation can mitigate problems if timely planting and good weather are not realized. Objective 3: Perform education and outreach activities to enhance producer adoption of organic production practices 1) Major activities completed / experiments conducted: A meeting of project partners was held on October 21, 2022 with presentations on progress, markets, economics, and discussion of project plans for the coming year. A public information meeting was held on March 28, 2023 where project information was shared. Approximately 17 people attended the meeting, including small and large acreage farmers, ag professionals, and members of the public. Topics covered included project research design and findings, economics of organics, organic markets, and USDA organic certification. A field day event was held on August 4th, 2023, at the MO demonstration site. Approximately 15 farmers attended the plot tour, where information was shared about the project and demonstrated successful organic corn and sorghum production. A tour at the MO site was conducted on August 28, 2023, and attended by U.S. Representative Eric Burleson, the Dean of the university system, regional farmers, professors, and executives in ag sector organizations. Numerous social media items were posted with web links, and on-line and in-person meetings were held, to share research and demo site information. 2) Data collected: The project recorded names and contact information of farmers who are interested in organic production, creating a list for direct distribution of project results and information. 3) Summary statistics and discussion of results: n/a 4) Key outcomes or other accomplishments realized: The project generated information from its research and demonstration plots that was shared with the public through a winter meeting that discussed the project and its results, and a summer field day at a demo site. Other dissemination took place through social media, websites, direct E-mail, and through virtual and in-person meetings. Organic Praxis Workshops A public workshop was held on March 18th, 2023, with 17 attendees. Information was shared on the project, its research, and economics of organic crop production. Economic data suggests that the per-acre break-even yield for organically produced crops is lower than that of conventionally produced crops. Publications **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: Nothing Reported 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? All research plots and demonstration sites will continue with the planned protocols. Using information drawn from the performance of the treatments through the challenging weather conditions in the first year, the project will adjust management practices to address the most problematic issues. In fall 2022, a project team meeting will be convened to discuss optimal practices for winter cover crops and how best to move into the cropping season of summer 2023. Earlier planting dates, more aggressive and timely cultivation, and higher management levels and other adjustments are under consideration. Outreach to and communication with farmers will proceed, along with planning and conducting organic certification and production workshops. **Impacts** What was accomplished under these goals? Impact The project's goal is to make organic farming a viable option by providing production information tailored to conditions in the Mid-South. In its first year, the project focused on establishing research and demonstrations as described. Research plot results suggest that establishing vigorous winter cover crops, planting the summer crop early in the spring, and timely cultivation are the most beneficial practices. These results were evident despite a region-wide summer drought that limited crops and accelerated weed growth in these non-irrigated plots. At the larger demonstration plots, winter grazing was effective, as were alternative practices such as switching to forage soybean production, which offered value. The project revealed barriers to organic production, such as the need for irrigation, ample seeding rates, and early planting dates. Objective 1: Conduct replicated research trials on organic crop management approaches 1) Major activities completed / experiments conducted: Replicated research plots comparing four management systems were established; no plots received irrigation. All plots were planted with a rye/clover mix cover crop in fall, 2021. The 2022 crop was soybeans. In the conservation system (no-till), the cover crop was roller crimped and the soybeans were planted. In the integrated system, calves grazed both no-till and tilled plots followed by soybean planting. In the profit-driven system (conventional tillage) soybeans were planted after cereal rye harvest. 2) Data collected: Soil samples were taken in fall 2021. Data collected included cover crop biomass, grazing time, cattle weight gain, crop planting rates, crop stand counts, crop losses to drought and pests, weed types and counts, pest pressure, crop yields, and rainfall. Insects and pests were negligible. Multiple weed species were identified and recorded. 3) Summary statistics and discussion of results: The cover crop, over winter management, grazing, and tillage

worked well. High rainfall in the spring made soybean planting difficult. Into summer, drought and heat decimated the plots, preventing soybean development while promoting weed growth. Deer grazed the plots, stripping leaves from about 90% of soybean plants; regrowth was negligible. Disease and insect problems were minimal. Johnsongrass was the most problematic weed. Differences were observed between treatments. In the conservation plots, the roller crimper created a mat that provided reasonable weed suppression. In the integrated system, plant stands and growth were good. The profit-driven system plots, planted in August, demonstrated better soybean growth. As the season progressed, tillage proved to be the most effective practice for weed control across treatments. 4) Key outcomes or other accomplishments realized: Data and observations suggest practical lessons for organic management: Earlier fall planting of the cover crop is important to establish enough cover. Grazing is valuable for weight gain, but grazing too long allows weeds to outgrow the cash crop. Earlier crop planting dates and higher seeding rates are beneficial. Consistent and aggressive cultivation is needed to control weeds. Objective 2: Implement geographically diverse, farm-scale trials to substantiate best management practices observed from Objective 1 1) Major activities completed / experiments conducted: The project established three farm-scale sized demonstration plots. All plots were planted with a cereal rye-clover mix winter cover crop. No plots received irrigation. All sites were affected by summer drought and high temperatures. Arkansas Demonstration Site. The site covers 12 acres, split between the conservation and profit-driven systems. On the no-till side, soybeans were planted into the cover crop and roller crimped. The rye formed a thick mat, suppressing weeds. On the conventional tillage side, the rye was taken to harvest, and the plots planted to soybeans. By late June, the no-till side had a good stand of soybeans with about 240,000 plants/A and up to 28 inches tall. Moderate weeds were limited by shading. Crop potential was good, but the plot was severely grazed by deer, allowing weeds to outgrow the soybeans. The conventional tillage side, with soybeans planted after rye harvest, grew with August rains. The soybeans were cultivated as needed. Stand counts were about 150,000 plants per acre, and up to 30 inches tall. In this system, cultivation has been key to crop success. Missouri Demonstration Site. The site covers 12 acres and applied the integrated system, divided into four subplots, two in conventional tillage and two in no-till. The cover crop was grazed with heifers in the spring. After grazing, all subplots were planted to soybeans, with two plots planted at 160,000 seeds/A, and two at 320,000 seeds/A. Low/high seeding rates were used to test the ability of soybeans to compete with weeds. Weed pressure was very high in early summer. In the lower rate plots, the weeds overtook the soybeans by July, leading to crop failure. In the higher rate plots, the denser stand competed better with weeds. The soybeans had good early growth but were stressed by drought, allowing weeds to take over. Crop failure was expected, and the soybean/weed mixture was cut for hay. Yields averaged 1,245 lbs. per acre, and forage analysis averaged about 14.5% protein, 32% ADF, 48% NDF, 61% TDN, and 1.2 MCal/lb. digestible energy. Tennessee Demonstration Site. The site covers 20 acres, split between the conservation and profit-driven systems. Heavy fall rains damaged the cover crop seed and resulted in a reduced stand. The no-till side was roller crimped in June and planted with soybeans. The cereal rye was harvested on June 27th (yield about 100 lbs/A), and the plot planted to soybeans. Conditions were very dry and temperatures high, which damaged the young soybeans and allowed weeds to grow. The soybeans were considered a loss in early August. 2) Data collected: Soil sampled fall 2021, with analysis. Data collected included cover crop biomass, grazing time, cattle weight gain, crop planting rates, crop stand counts, weed types and counts, pest pressure, crop yields, and rainfall. As with the research plots, damage from insects and diseases was minimal. Weed pressure was the most significant issue with a number of problematic weeds across all three sites. 3) Summary statistics and discussion of results: Field preparation, planting, and stand establishment was good for the cover crop at all sites. The Tennessee site had much winter kill that thinned the cover crop, and heavy spring rains delayed soybean planting. At the Missouri site, stands in the higher rate plots were good compared to the lower rate plots. Heat and severe drought hampered the crop; early planting dates would have benefited the crop. At the Arkansas site, stands were good, and cultivation contributed to a reasonable late crop. On the no-till side of the demonstration site, drought and deer decimated the plot. Early economic analysis of the systems suggests that a break even yield for organic production is significantly lower than a comparable crop under conventional, non-organic production for field practices as employed at our demonstration sites. 4) Key outcomes or other accomplishments realized: Overall, for all three demonstration sites, drought and heat had the greatest adverse effects, while late planting dates also contributed to problems. Objective 3: Perform education and outreach activities to enhance producer adoption of organic production practices 1) Major activities completed / experiments conducted: A list of interested farmers in the target area has been created, with contact information. 2) Data collected: names and contact information. 3) Summary statistics and discussion of results: n/a 4) Key outcomes or other accomplishments realized: n/a Organic Praxis Workshops No activities this period. **Publications**

↑ Return to Index

Building a Lasting Seed Development Network Through an Online Organic Seed Growers Conference

Accession No.	1026618
Project No.	WN.W-2021-02894
Agency	NIFA WN.W\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34892
Proposal No.	2021-02894
Start Date	01 SEP 2021
Term Date	31 AUG 2022
Grant Amount	$46,252
Grant Year	2021
Investigator(s)	McCluskey, C.; Colley, MI, .; Hubbard, KR, .
Performing Institution	ORGANIC SEED ALLIANCE, 210 POLK ST STE 1, PORT TOWNSEND, WASHINGTON 98368-6739

NON-TECHNICAL SUMMARY

Seed is the fundamental input of our food chain, yet we hear little about how it is produced or the benefits of growing it for organic farming systems. In 2020, as COVID-19 cases skyrocketed so too did demand for organic seed, exacerbating longstanding supply limitations. Convening the organic seed community to share innovations, critical needs and practical experiences will bolster organic seed production and public cultivar development, enhancing the supply and resilience of organic food systems. By adapting a successful national organic seed conference from a gathering in Corvallis, OR to a virtual event via a new curriculum delivery and community-building network, access to resources and support will expand for participating seed growers, farmers, plant breeders, university researchers, certifiers, food companies, seed companies and advocates. Through this project, the decentralized organic seed community that gathers nationally only once every two years will connect in real-time from their home regions and engage with each other via the network on an ongoing basis, providing unprecedented potential for economic, social and agronomic advances.

OBJECTIVES

This project will provide research, education and policy resources and a forum to share critical needs and practical experiences to organic seed growers, farmers, plant breeders, university researchers, certifiers, food companies, seed companies and other organic agriculture practitioners in new and innovative ways. By adapting a successful national organic seed program from a gathering in Corvallis, OR to a virtual event with online delivery via a new organic seed network platform, organic agriculture will be promoted through improved organic seed production, breeding, and policy development \-- progress that will continue indefinitely through the expansion of networking resources developed for this conference.The long-term goals of this conference are to: 1) increase the production and use of quality organic seed; 2) build and bolster regional and national seed systems and policies to support them; 3) foster the development of organic breeding projects; and 4) facilitate the outreach and dissemination of scientific findings and work specific to organic seed and breeding. The overarching goal of the Organic Seed Growers Conference (OSGC) is to convene diverse stakeholders to build relationships and exchange ideas to foster a national network of thriving regional seed systems that respond to the needs of organic farmers and the markets they serve. This project advances these goals in new ways by expanding

accessibility and participation via online delivery and doing so through a networking platform that will foster ongoing collaboration, peer-to-peer learning, and collective action. Expanding participation and access to the national organic seed conference requires effective outreach and educational objectives, including: 1) promoting the conference to all stakeholders; 2) providing targeted outreach to increase leadership and engagement by communities of color working with seed; 3) developing an easy-to-use online platform for conference registration, program delivery, networking opportunities and ongoing group engagement; 4) delivering the conference live online; 5) recording workshops of interest to eOrganic users; 6) a hosting a digital poster gallery to report out on OREI projects other organic research; 7) publishing downloadable proceedings of the conference; 8) developing online communities within the networking platform for ongoing collaboration and collective action to continue momentum after the event. Accomplishing these objectives will cultivate vital collaborative relationships, provide a platform for ongoing collaboration and peer-to-peer learning, and ultimately increase the production and use of organically produced seeds and varieties specifically adapted to organic farming systems.

APPROACH

Methods for organizing and delivering the last 10 OSGC events \-- planning, promotions, proposal and agenda development \-- will be followed using the successful strategies employed in the past. The critical methods distinguishing this project focus on the development of an online network for participant engagement and conference program delivery. Efforts Online network development Workshops, including eOrganic webinars Panel discussions Poster sessions and research presentations Proceedings Evaluation Individual workshop evaluations will be available through the networking app as each session closes; main conference evaluations will be available anytime during the conference and up to two weeks afterwards. Follow-up evaluations will be shared via the network to all participants to gauge the impacts (e.g., adoption of new practices, change in knowledge, change in condition) three months and one year after the conference, with custom questions for specific stakeholder communities on the network. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: The virtual 2022 Organic Seed Growers Conference, held February 4-11, attracted over 1,200 seed enthusiasts and professionals from 48 US states as well as many international participants. This represents a 300% increase in attendance over the 2020 conference held in-person in Corvallis, OR. Outreach for the event broadened the traditional audience significantly \-- 53% of registrants were first time attendees. The event was offered virtually on the Organic Seed Commons platform and registration fees were on a sliding scale to ensure that cost was not a barrier to participation and to provide access to historically underrepresented growers of color.Of the 1,203 attendees and speakers, 603 registered at the \"seedling\" or free level. Participants registering as attendees were invited to select any number of identifers. Attendee registrants self identified as 43% farmers or seed growers, 23% as students, 12% as plant breeders, 12% as seed company representatives, 11% as university researchers;others identified as gardeners, seed policy advocates and nonprofit organization representatives and other categories. Of the 738 registrants who volunteered demographic information, 33% (220) identified as non-white/European. Of the non-white participants, 25% identified as Black, 25% as Latino, 17% Indigenous, 17% Asian, 7% South Asian, 5% Middle East/Arab, and 4% Pacific Islander. Attendees indicated that they heard about the event through multiple outlets: email invitations, OSA social media, University professors, partnering nonprofit organizations, seed companies and word of mouth. The conference offered 102sessions, including 70 presentations or roundtable discussions,40 of which were live sessions; other sessions offered networking, entertainment or media sharing opportunities. Fourteen sessions were offered with live Spanish and French translation. Many of the live sessions were recorded; 33 of them can be accessed from a play list on the eOrganic video channel where recordings have been viewed a total of 2,440 times. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Opportunities for training and professional development were offered as educational sessions during the conference. Networking sessions by region and topic and practical \"how to\" sessions received positive feedback on our survey. The most popular of these sessions was \"Small to Medium Scale Seed Cleaning Equipment\" (153 recording views), \"Seed Production for Market Growers\" (132 views) and \"Running a Small Online Seed Company\" (121 views). Other networking and round-table sessions included: Labor in the Organic Seed Movement Addressing Seed Grower Concerns with Organic Certification Discovering, Connecting and Inspiring a Southeast Seed Network Learnings from Participatory Grower Networks Seed Growers Speak Out About Climate Change Understanding Seed IPR (Intellectual Property Rights) Building Your Seed Brand: Cultivating the World We Dream of While Growing a Sustainable Business Farming and Disability Meet-up BIPOC Seed Growers Meet-up Culinary Corn Meet-up Youth Seed Growers Meet-up Flower Seed Growers Meet-up Producing Seed On Contract Meet-up How have the results been disseminated to communities of interest?A website article was published and shared with all active OSA contacts through our newsletter and viewed 84 times. A dedicated webpage includes links to all conference assets and has been viewed 12,239 times. The proceedings of the conference are posted online and have been downloaded 51times. A post-conference debrief with conference staff and the planning committee illuminated how the conference was helpful

to the communities each organizer represents. Several listening sessions with attendees are planned for February 2023 to inform the next event. New arrivals to the Organic Seed Commons platform have access to all of the session information, online discussions and video recordings, which continue to be watched on eOrganic. 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 accomplished its overarching goal: to convene diverse stakeholders to build relationships and exchange ideas to foster a national network of thriving regional seed systems that respond to the needs of organic farmers and the markets they serve. The virtual conference increased past attendance by 300%, and served attendees representing 48 states, all major demographic groups and a diversity of seed practitioners (as described in the audience section). The success of the conference was measured through surveys, participant observers and a professional evaluation by an educational consultant. Surveyed participants described the 11thOSGC as, \"inspiring,\" \"transformational,\" \"connective/community-building\" and \"well-run.\"97% of the respondents to the evaluation survey (76 respondents/a 6% return rate) rated the overall OSGC event as: \"excellent\" (54%) or \"good\" 43%. The data indicates that the strength and draw of the conference is the breadth of its content and how it is able to engage participants' intellect, curiosity, creative and relational spirit, while providing practical advice and application. The specific objectives we set out to achieve were accomplished, as described below. 1) Promoting the conference to all stakeholders Cultivating a diverse and representative conference committee and event partnerships was key to success in promoting the conference. While OSA delivered multiple digital invitations through our database of over 15,000 contacts and a mailing to past program participants, networking by our planning committee and partners extended our reach. Conference committee members represented diverse geographies and seed grower groups: Bonnetta Adeeb, UJAMAA Cooperative Farming Alliance and Steam Onward, Maryland; Nate Kleinman, Experimental Farm Network, New Jersey; Petra Page-Mann, Fruition Seeds, New York; Alexis Yamashito, Southern Exposure Seed Exchange, Virginia; Michael Lordon, OSA, Michigan; Rue Genger, University of Wisconsin-Madison, Wisconsin; Cathleen McCluskey, OSA, Wisconsin; Karl Sutton, Fresh Roots Farm, Montana; Natalia Pinzon, Farmer Campus, California; Alice Formiga, eOrganic, Oregon; Rebekah Korenowsky Woods and Cara Loriz, OSA. Conference promotions were also shared by Seed Savers Exchange, Organic Farmers Association, Tilth Alliance, Midwest Organic & Sustainable Education Services, Native Seed Search and many others. 2) Providing targeted outreach to increase leadership and engagement by communities of color working with seed; A key strategy in reaching communities of color working in seed was ensuring that they were represented on the conference planning committee and in the agenda. The call for proposals uplifted \"Building equity and justice in organic seed communities\" as the topmost theme to be featured during the conference specifically encouraged \"proposals that include growers from Black, Indigenous, People of Color, and LGBTQIA+ seed communities.\"The conference featured 180 presenters. Of the speakers who selected demographic identifiers, 61 in total, 25 identified as non-white with Asian, Black, Latino and Indigenous leaders represented. Success in reaching communities of color is reflected in the participant data. Of 670 registrants who selected demographic identifiers, 220 identified as non-white/European; please see more details in the Targeted Audience section. 3) Developing an easy-to-use online platform for conference registration, program delivery, networking opportunities and ongoing group engagement; The future use and value of the Organic Seed Commons networking platform was supported by data from conference participants. The survey asked, \"How do you see yourself using the Organic Seed Commons networking platform after the conference? Do you have any suggestions for how it could be improved?\" 70% of survey respondents said they plan to use the Organic Seed Commons after the conference and they articulated specific uses. Most saw it as a way to (1) view conference sessions that they missed; (2) peer sharing of resources and knowledge, particularly regionally; and (3) access to good resources. Over 700 more seed practitioners have joined the platform since the conference. Retention of users on the platformed has remained strong, with 50% of members retained over a 30 day period. 4) Delivering the conference live online The conference hosted 102 sessions delivered from Feb 4-11, with Monday, Feb 7 as a hiatus day. High priority topics were featured during \"Main Stage\" sessions with no competing programming; other sessions were delivered concurrently with up to four other workshops or discussions. Each session drew approximately 30 to 200 attendees. The virtual nature of the 11thOSGC was experienced by participants as very positive. Respondents praised: Global accessibility and diversity Significantly reduced costs to participants Climate change/ecological footprint The space felt more open and inviting \"less cliquish\" Generally, easy to navigate/user friendly. Staff back-up was outstanding Participants remarked they could pace themselves and not get overwhelmed or overloaded. 5) Recording workshops of interest to eOrganic users 33 recordings of the conference are posted as a playlist oneOrganic's video channel and have been viewed a cumulative 2,442 times (not including live participation). 6) Hosting a digital poster gallery to report out on OREI projects other organic research The poster session was presented as live Q&A sessions with the researchers and posted to the Organic Seed Commons platform as videos that continue to be viewed. <https://www.organicseedcommons.org/posts/organic-seed-growers-conference-2022-virtual-research-posters>. Six posters on organic research ranged from quality selection methodology for organic maize to tomato varieties developed for improved flavor and disease resistance and adaptation to the Upper Midwest. In addition to the

poster sessions, researchers offered full presentations on six additional topics. All of these reseach presentations are viewable on the eOrganic site and Dr. Walter Goldstein's presentation on Seed Endophytes, Rhizophagy, Nutrient Density, Nitrogen Efficiency and Fixation in Corn is the most viewed session with 255 views. 7) Publishing downloadable proceedings of the conference The Proceedings of the 11th Organic Seed Growers Conference is free to all and downloadable from the Organic Seed Alliance website and is also accessible from the eOrganic website. The publication presents abstracts of 63 presentations representing the work of over 180 researchers, growers and seed advocates. Abstracts are organized according to these categories: panel discussions (presentations and panelist interactions), round-table discussions (small group leading an open discussion with attendees), presentation of research, research poster abstracts, lightening talks (for non-research topics), farm tours, demonstrations. The proceedings have been downloaded a total of 51 times from growers in 19states. 8) Developing online communities within the networking platform for ongoing collaboration and collective action to continue momentum after the event. Programming for the conference included topical and regional meetings hosted in dedicated groups within the Organic Seed Commons. The regional seed networks continue to engage attendeeswith new events hosted on the platform throughout the year. Regional networks are active forthe Pacific Northwest, Hawaii, California, Midwest, Intermountain West,Northeast, Southeast. Topical groups include Seed Policy Network, Carrot Breeding Network, a \"How To\" sharing space and an \"Ask the Expert\" topics post. The regional networks are some of the most active segments of the Organic Seed Commons. In addition to ongoing conversations within each network's activity posts,online events have been hosted on the platform for the Midwest, California and Hawaii networks. **Publications** - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Lordon, M. (editor). 2022. Organic Seed Growers Conference Proceedings. February 4 - 11, 2022, Virtual. Organic Seed Alliance, Port Townsend, WA. 164 pp. - Type: Websites Status: Published Year Published: 2022 Citation: Organic Seed Commons 2022 Organic Seed Growers Conference Event Space https://www.organicseedcommons.org/posts/welcome-22333381

↑ Return to Index

Systems-based Approach to Enhance Quality, Safety, and Shelf Life of Organic Tree Fruit in the Pacific Northwest

Accession No.	1026806
Project No.	WNP00867
Agency	NIFA WN.P\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34913
Proposal No.	2021-02949
Start Date	01 SEP 2021
Term Date	31 AUG 2025
Grant Amount	$1,499,887
Grant Year	2021
Investigator(s)	Amiri, A.; Gallardo, KA.; Critzer, FA, MI.; Torres, CA.; Sallato Camona, BE.
Performing Institution	WASHINGTON STATE UNIVERSITY, 240 FRENCH ADMINISTRATION BLDG, PULLMAN, WASHINGTON 99164-0001

NON-TECHNICAL SUMMARY

Washington State provides nearly all organic pome fruit grown in the USA with an estimated annual farm gate value of a half billion dollars. There are currently 30,000 certified organic acres of pome fruit in the state and it is expected to reach 38,000 by 2022. This quickly expanding organic industry was possible under the dry climate of central WA which keeps disease pressure low and enhanced fruit quality. However, postharvest stakeholders lack effective tactics to maintain quality, safety, and mitigate postharvest decays which combined can results in annual crop loss up to 35%. This integrated and interdisciplinary project aims to bridge pre and postharvest practices and develop a systems approach to address critical challenges by: 1) developing effective and timely preharvest organic sprays to limit fruit infections by postharvest pathogens and define adequate harvest window for enhanced postharvest fruit quality, 2) assessing non-chemical methods, i.e. thermotherapy and dynamic controlled atmosphere, to extend fruit quality, reduce disorders and contaminations by fungal pathogens and human pathogens in storage, and 3) evaluate the efficacy and feasibility of safer anti-microbial and anti-fungal coatings in mitigating human and decays pathogens in cold storage and retail stores. Economic feasibility of proposed approaches will be assessed, and a strong outreach program will ensure effective technology transfer to large and underrepresented organic stakeholders in the PNW and other growing regions. The long-term goal of this project is to support resilience of quickly expanding industry to meet increasing consumer demand for safe and high-quality fresh produces

OBJECTIVES

Pome fruit growers and packers lack sustainable solutions that fit organic guidelines to grow, store, and pack fruit safely and efficiently. The long-term goals of this project are to empower organic pome fruit stakeholders with novel and more effective approaches to reduce fungal decays, physiological disorders, and human pathogen contaminations. Specefic objectives are:1- Conduct on-farm research to assess the efficacy of enhanced preharvest management practices to fight fungal infections and improve fruit quality in storage2- Conduct lab- and postharvest-research to assess efficacy of non-chemical methods to improve quality and reduce fungal decays3- Assess the efficacy of postharvest organic antimicrobial coatings to mitigate microbial and fungal contaminations in organic fruit4- Develop and deliver outreach activities to organic stakeholders

APPROACH

Activity 1.1. On-farm assessment of new organic materials to implement a timely effective seasonal spray to mitigate fruit infections by field pathogens. We propose to expand our previous study by conducting trials in organic-certified farms to develop a timely spray program based on the epidemiology of major diseases and using the most effective organic materials selected from our recent work. The four most effective materials will be selected and applied in two commercial orchards planted to the cultivar Honeycrisp, a high value cultivar and one of the most susceptible cultivars to many postharvest pathogens and disorders. If our suggested spray program(s) are found to be effective on this cultivar, recommendations will easily apply to other less susceptible cultivars with minor adjustments. Same spray program trials will be conducted at two commercial orchards: Godwin orchard in north WA (Tonasket) and BZBlackrock orchard in south WA (Moxee). The rationale is to test proposed management program(s) on a larger commercial scale in different environmental conditions to ensure final recommendations fit the needs of most stakeholders. At each site, a one-acre organic block will be divided into 2 sub-blocks. One sub-block will be sprayed following the current \"standard\" grower spray (0-7 days preharvest) and the second sub-block will be sprayed using our proposed \"timely\" program of 4 sprays throughout the season, i.e., at petal fall, fruitlet, green fruit, and 3 days preharvest. Each sub-block will be divided into 4 smaller sub-block replicates with an equal number of trees. Products will be provided to the cooperators who will apply them using the standard spray equipment (air-blast) that they use in their orchards. At commercial maturity, fruit from each sub-block will be harvested separately by the cooperators in collaboration with PD-Amiri and his team. Two sets of fruit will be collected at harvest to assess the efficacy of the spray programs. Activity 1.2. Effects of preharvest applications of organic ethylene blockers to extend the harvest window and postharvest quality in long-term storage. Organic formulated AVG will be applied at different doses and timings before harvest in two-organically-certified commercial orchards (Stemilt-cooperator) in central WA. We will use randomized complete block design with 10 trees per block, 3 blocks per plot. Fruit (20 per block) will be sampled 25 days before harvest every 7 and 3 days to assess maturity progression by measuring flesh firmness, soluble solids content (refractometer), starch degradation, titratable acidity (malic acid equivalent), skin color (using a colorimeter and subjectively as % coverage), ethylene production (gas chromatographer), respiration (O2and CO2meter), and chlorophyll degradation (index of absorbance differences \IAD\ using DA meter). Fruit maturity and quality, including incidence and severity of physiological disorders and diseases, will be evaluated at harvest and postharvest after storing the fruit in regular RA, CA, and DCA at 0-1°C. After 2, 4, and 8 months of storage, 60 fruit per replicate block will be used to measure maturity indices and physiological disorder incidence and severity after 1 and 7 days at 20°C to simulate shelf life. Treatment differences will be assessed using analysis of variance (P\<0.05) and mean separation with Tukey test (P\<0.05). For non-parametric data,the Kruskal-Wallis ANOVA test will be used to assess treatment differences and Dunn\'s test for mean separation.These results will be used to assess the economic benefits (Obj. 4) of AVG applications.Sub-Obj. 2.1. Impact of regular and dynamic controlled atmospheres on life of organic fruit and fighting fungal infections in storage. Activity 2.1.1. Effect of dynamic controlled atmosphere (DCA) on fruit quality and physiological disorders \Torres, Year 2 & 3\. Honeycrisp and Gala apples will be picked from two commercial organic orchards and stored in RA, CA (O2 and CO2 set points appropriate for the cultivar), and DCA using respiratory quotient based on initial O2 level at 1°C or 3 °C depending on the cultivar. All these storage regimes will be set at the fruit handling building at TFREC; DCA system will be managed using LabPods (Storage Control System, MI, USA) (Fig. 4). Fruit maturity variables (flesh firmness, soluble solids content, starch degradation, titratable acidity, skin color, ethylene production, respiration, and chlorophyll degradation) and presence of physiological disorders will be evaluated after 3, 4, 6, and 8 months of storage plus 1 and 7 days at 20 °C to mimic shelf life and complete cold-chain scenarios (retail stores). One hundred fruits per replicate and time-point postharvest will be used for these measurements. Treatment differences will be assessed using ANOVA (P\<0.05) and mean separation using Tukey\'s test (HSD, P\<0.05). For non-parametric data Kruskal-Wallis ANOVA test will be used to assess treatment differences and Dunn\'s test for mean separation. These results will be used to assess the economic benefits of DCA (Obj. 4). Activity 2.1.2.1-Efficacy of DCA against four major postharvest pathogens on artificially inoculated detached fruit (Year 1-2). Trials conducted in the 2019-20 season have shown potential of DCA (O2 = 1.5%, CO2 = 0.8%) to reduce decay incidence of four major postharvest pathogen in comparison to regular CA (O2 = 4%, CO2 = 0.8%) and RA (Fig. 3) although differences were not always significant. In Year 1 and 2 of this project, we plan to optimize DCA systems by testing different concentrations of O2 and CO2 until decay is reduced to the minimum without affecting the fruit quality. Herein, we will focus on 4 major postharvest pathogens: B. cinerea, Neofabraea perennans, P. expansum and M. piriformis. For the first two pathogens, Gala apples will be inoculated, while on the trees, with spore suspensions at 500,000 spores/ml 15 days prior to harvest to mimic pre-harvest infections. For P. expansum and M. piriformis, which infect fruit mainly at and after harvest, Gala apples picked at commercial maturity, will be surface disinfected in sodium hypochlorite, rinsed with sterile water, and inoculated with spore suspensions of each pathogen at 500,000 spores/ml. Four replicates of 25 fruit each (total of 100

fruit/treatment) previously randomized using a randomized complete block design (RCB) design will be used. Fruit will be stored in RA, CA, and DCA. For RA treatment, fruit will be incubated in regular cold rooms at TFREC. For CA and DCA treatments, LabPods containers will be used since TFREC does not possess cold room with CA or DCA capabilities. The LabPods (Fig. 4) will be stored in the same cold room used for RA to ensure similar temperature and humidity. Decay incidence and severity (lesion diameter) will be determined after 2, 4, 6 and 8 months of storage and data will be subjected to a one-way ANOVA analysis with the treatments being the variables and means will be separated with Student\'s t-test at p value ≤ 0.05. Progress 09/01/23 to 08/31/24 Outputs Target Audience:The main target audience was pome fruit growers and packers in Washington State PD: Amiri targeted organic growers and packers to advise and recommend on best management practices to manage postharvest disease Co-PD Torres targeted organic packers to conduct research and advise on physiological disorders and fruit quality Co-PD Critzer targeted organic packers to conduct research and advise, provide recommendation on food safety Co-Ps Gallardo and Murphy conducted extension activities with organic growers and packers to collect data for the economic analysis. Additional audience included other industry stakeholders and allied industry providers in addition to graduate students and scientists. Changes/Problems:Changes Obj. 1-Activity 1.2. New trials were not planned for 2023 season because Retain OL (AVG formulation for organic apples) did not get the experimental use approved. Problems Obj. 1-Activity 1.1. Our packinghouse collaborator misplaced the fruit intended for our trial which require redoing the trial in the next period Obj. 1-Activity 1.2. Retain OL (AVG formulation for organic apples) did not get the experimental use approved. Obj. 3-Activity 3.1.1. Some phytotoxicity was observed on apples treated antimicrobial. Trials will be repeated in 2024-25 using different doses and method of application What opportunities for training and professional development has the project provided?Training: A PhD student in Economics (Nickson Cabote) is being trained to conduct price analyses of organic apples across each month within the marketing season, to evaluate the effect of pre-harvest and post-harvest treatments on the grower\'s profitability. Sadat Amankona, \"Optimization of organic apple storage\", Ph.D. in Horticulture. Aug 2022 - present. Clayton Haskel, a Scientific Assistant, was trained in Amiri lab to conduct pathology work Emma Ewald, an undergraduate student, was trainned in organic disease management in the lab and field in the Amiri lab Professional Development -PD Amiri and a Scientific Assistant attended the Plant Health meeting in Memphis TE in July 2023. -Tour and technical discussion. Hispanic Orchard Employee Education Program (HOEEP)- Wenatchee Valley College (39 attendees, 03/08/2023). How have the results been disseminated to communities of interest?Talks: Amiri A., Fomba J. 2023. Can dynamic controlled atmosphere help reduce postharvest diseases of pome fruit? VII International Conference Postharvest Unlimited, Wageningen, Netherlands, May 15th Amiri A. 2023. Impact of pre and postharvest management practices on decay diversity and frequency of pear in the U.S. Pacific Northwest. XIV Pear International Symposium, Stellenbosch South Africa, January 25th Amiri A. 2023. Managing decays in organic pome fruit. Annual Meeting of the Washington Fruit Association, Kennewick, December 6th Amiri A. 2023. Efficacy of organic materials applied preharvest to control fruit rots in storage. Columbia Basin Tree Fruit Club, Kennewick, July 26th Torres, C.A. 2023. \"Washington experience of link between pre-harvest conditions and postharvest outcomes\" (Keynote). Hortgro post-harvest symposium day. Hortgro Science, South Africa (June 8, 2023). Torres, C.A. 2024. Variabilidad climática y su efecto en la calidad de manzanas y peras en guardas prolongadas (Keynote). VIII Jornadas Anuales de Postcosecha, Santiago, Chile (Aug. 21-22, 2024). Torres, C.A. 2024. \"Storage Technologies for organic apples,\" 12th Annual Pace Postharvest Academy, Pace International LLC, Clee Elum, United States of America (May 8, 2024). Torres, C.A. 2023. Honeycrisp and effects of climate. Cornell Storage Workshop, University of Cornell, 404 Plant Science Building, Ithaca, NY (Aug. 16, 2023). Torres, C.A. 2023. \"Impact of hot weather on postharvest fruit quality in apple and pear\". ASHS Webinar Series (Feb. 8, 2023). Torres, C.A. 2023. Preharvest conditions of fruit quality and storability. WSTFA 119th Annual Meeting & NW Hort Expo, Washington State Tree Fruit Association, Richland, WA, United States of America (Dec. 6, 2023). Torres, C.A. 2023. Managing fruit quality and decays in organic pome fruit. WSTFA 119th Annual Meeting & NW Hort Expo, Washington State Tree Fruit Association, Richland, WA, United States of America (Dec. 6, 2023). Amankona, S. 2024. Organic Gala apple: Fruit quality during the 2022/2023 long-term. Royal City Growers Meeting, Royal City, WA (Feb, 8, 2024). Amankona, S., Torres, C.A. 2023. Organic Gala: Fruit quality during the 2022/2023 long-term storage season. WSTFA 119th Annual Meeting & NW Hort Expo, Washington State Tree Fruit Association, Kennewick, WA, United States of America (Dec. 4, 2023). Torres, C.A. 2023. \"Update on season effect on apple quality during long-term storage\". Yakima Pomeclub, Yakima, WA (78 attendees, 11/16/2023). What do you plan to do during the next reporting period to accomplish the goals?PD-Amiri: Obj. 1-Activity 1.1. Field trials will be repeated at two commercial orchards in central WA to assess the efficacy of develop organic spray program Obj. 2-Activity 2.1.2.2. Evaluate the efficacy of dynamic controlled atmosphere to control postharvest decays in commercial fruit (season 2). Obj. 2-Activity 2.2.1. Finish in vitro work to assess spore kill temperature on major posthravets pathogens Obj. 3-Activity 3.1.1. Conduct year 2 trials to assess efficacy of antimicrobial coatings against major postharvest pathogens Co-PD Torres: Obj. 2- Activity 2.2.1. Data analysis for season 2023-2024 and storage trial for 2023-2024. Fruit will be sourced from the same Gala and Honeycrisp commercial blocks used in previous seasons. Obj. 2- Activity 2.2.1. Hot water treatments

will be performed in 2024 (Gala, Honeycrisp) and fruit quality evaluated at different intervals for 10 months in air and controlled atmosphere storage. Co-PD Critzer: Obj. 3- Activity 3.1: Work will commence with this crop year (fall 2024). Upon completion, we will understand how washable coatings impact survival of the foodborne pathogen (L. monocytogenes) in addition to fungal decay causing organisms during long-term controlled atmosphere storage. Co-PD Gallardo (Objective 4) Estimate the maximum percentage of decay losses that would offset fluctuations in organic prices during the season. Incorporate pre-harvest chemical application data and seasonal variation in prices to the partial-budgeting analyses. Co-PD Murphy and PD Amiri (Objective 5). PD Amiri will Organize a field day in north central Washington PD-Amiri and Co-PD Torres will organize a ½ warehouse day. Co-PD Murphy will organize a field day in southcentral WA. Impacts What was accomplished under these goals? Objective 1: Conduct on-farm research to assess the efficacy of enhanced preharvest management practices to fight fungal infections and improve fruit quality in storage \Research\ Activity 1.1. On-farm assessment of new organic materials to implement a timely effective seasonal spray to mitigate fruit infections by field pathogens. \Amiri\. Field trails were conducted in a commercial Honeycrisp orchard located in Royal City, WA. A 7- acres block was divided into 2 sub-blocks; one was sprayed according to the standard grower (SGSP) spray program while the second sub-block was treated using a Research-based spray program (RBSP)based on new materials and different spray times. Apples were harvested from each sub-block at commercial maturity, stored in a regular atmosphere at 37°F, and inspected for decay every three months up to nine months. Results from this season revealed 2.5% of total decay in the subblock spayed using the RBSP compared to 8.9% in the SGSP subblock. Activity 1.2. Effects of preharvest applications of organic ethylene blockers to extend the harvest window and postharvest quality in long-term storage.\Torres\. No additional results from 2023-2024 trials. New trials were not planned for 2024 season because Retain OL (AVG formulation for organic apples) did not get the experimental use approved. OBJECTIVE 2: Conduct lab- and postharvest-research to assess efficacy of non-chemical methods to improve quality and reduce fungal decays \Research\. Activity 2.1.1. Effect of DCA on fruit quality and physiological disorders \Torres\. Apples (2 Honeycrisp commercial blocks and 1 Gala block) harvested in 2022 and evaluated during 2023 under different postharvest systems (Air, CA or DCA storage) up to 10 months showed differences in overall fruit quality and physiological disorders incidences between storage systems. Nevertheless, major differences were observed between Blocks. In general, Dynamic Controlled atmosphere (DCA) was able to retain fruit firmness and acidity better than regular air or CA storage. Flesh browning and CO2 injury were more prominent in DCA storage than the other systems, especially in Honeycrisp apples. In 2023, fruit from the same commercial blocks were harvested and placed into different storage regimes as in 2022. Postharvest evaluations are ongoing. After year 3, a comparison between seasons will be made in order to correlate fruit quality postharvest with weather events occurring during the growing season. Activity 2.1.2.2.-Efficacy of DCA against major postharvest pathogens in commercial fruit fruit (Years 2 and 3). \Amiri\. Organic Fuji apples harvested in October 2023 from a commercial orchard near Wenatchee, WA were stored at 35°F in three different storage atmospheres, i.e., room atmosphere, static controlled atmosphere (CA, 4% O2, 0.8% CO2), or dynamic controlled atmosphere (DCA, 0.6-08 % O2, 0.5-0.8% CO2). Trials are ongoing and data will be collected in September 2024 to simulate a one year storage. Activity 2.2.1 Optimal temperatures for apple cultivars \Amiri & Torres\. Hot water treatments (HWT, 49°C and 52°C) via immersions for 2 min were tested in Honeycrisp and Gala apples immediately after harvest. In Gala, fruit treated with 49°C and stored in CA (2%O2, 0.5% CO2) retained better firmness (+1.2 lb) than UTC and 52°C after 3 months into storage. In Honeycrisp, this was achieved by the 52°C treatment (+0.8 lb). The same effect was observed in fruit stored in air but with overall lower firmness values. There was no treatment effect on physiological disorders incidences. Hot water damage (brown skin) was observed in both HWT in Gala, with higher incidence at 52°C than at 49°C (35.5% vs 7.5%, respectively). Similar trends were observed in Honeycrisp with 7.5% vs 12.5% for 49°C and 52°C, respectively. OBJECTIVE 3: Assess the efficacy of postharvest organic antimicrobial coatings to mitigate microbial and fungal contaminations in organic fruit Activity. 3.1.1. Efficacy of antimicrobial coatings applied at harvest to protect from fungal contaminants in long term storage \Amiri\. Four antimicrobial coatings were applied as solo products at 2% and their combination at 0.5% each on organic Fuji apples in November 2023. Apples were then sprayed with spore suspensions of Penicillium expansum, Botrytis cinerea, Neofabraea perennans, or Phacidiopycnis washingtonensis. Treated apples were stored in a regular atmosphere at 35°F and inspected monthly for up to 6 months. For P. expansum, B. cinerea, and N. perennans, the combination of the 4 antimicrobial coatings was the most effective with the B. cinerea and M. perennans being the most effectively controlled. Activity 3.1.2. Evaluation of coatings to control foodborne pathogen surrogates in long term storage \Critzer\. No activity to report for this cycle. Work will commence in the 24-25 reporting cycle. Activity. 3.2. Efficacy of antimicrobial waxes applied during packing that can be used to protect against foodborne pathogens during distribution to the consumer \Critzer\. Work was completed for subobjective 3.2. Organic compliant carnauba wax incorporated with 2.0% (v/v) essential oil blend with equal parts oregano, cinnamon bark, clove bud, and coriander performed significantly better against Listeria monocytogenes, Shiga-toxigenic E. coli, and Salmonella enterica when compared to unwaxed or carnauba-only waxed Gala or Honeycrisp apples over 40 days. Concentrations less than 2% essential oil blend were not different than the wax-

only controls, but significantly different than unwaxed apples, most likely due to physical removal during the waxing process. Microgard (bacteriocin-based organic compliant antimicrobial) was not effective against any of the foodborne pathogens evaluated. OBJECTIVE 4: Economic analysis. Data about returns and costs of production have been collected for organic Gala and organic Honeycrisp. These data are used to develop the enterprise budgets. \Gallardo\ Apple enterprise budgets findings - published in 2023: Organic Gala: Based on the study assumptions, as of 2022, the first break-even return of organic Gala apples was about \$565 per bin. This is the minimum return needed for the owner-operator to cover the operation\'s variable costs. The second break-even return is about \$573 per bin, which is needed to cover the total cash costs and to be economically viable in the short run. The third break-even return is \$590 per bin, which is needed to cover the cash costs plus depreciation of machinery and buildings. The fourth break-even return is about \$709 per bin. When this return is received, the owner-operator would recover all out-of-pocket expenses plus realize a competitive return on equity capital invested in land, organic Gala apple orchard, machinery, equipment, and buildings. Failure to obtain this break-even return level means that the owner-operator will not receive a return on capital contributions equal to what could be earned in alternative uses. Organic Honeycrisp: As of 2022, the first break-even return of organic Honeycrisp apples was about \$583 per bin. This is the minimum return needed for the owner-operator to cover the operation\'s variable costs. The second break-even return is about \$593 per bin. The third break-even return is \$616 per bin, which is needed to cover the cash costs plus the depreciation of machinery and buildings. The fourth break-even return is about \$794 per bin. Price analyses: We procured data on organic prices for 10 years for organic Honeycrisp and organic Gala to estimate the price increases during the season Publications Type: Journal Articles Status: Published Year Published: 2024 Citation: Sanchez-Tamayo, M., B. Ruiz-Llacsahuanga, R. Raad, W. Kerr, F. Critzer. 2024. Inactivation of foodborne pathogens on gala apples by application of antimicrobial waxes. Food Control. 155, 110049. doi.org/10.1016/j.foodcont.2023.110049 Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Fomba J., Amiri A. 2023. Effectiveness of organic materials applied in the orchards to control postharvest diseases of pome fruits. Phytopathology 113-11-S3:96. Progress 09/01/22 to 08/31/23 Outputs Target Audience:PD Amiri has provided talks to an audience of organic pome fruit growers and packers estimated at 400 stakeholders in 2022. Co-PD Sallato has reached out to 25 apple growers of south-central WA to update them about pre and postharvest management and surveyed 10 organic stakeholders for current practices in pre and postharvest organic fruit systems. Co-PD Torres has reached out and trained Hispanic Orchard Employees in March 2023. Changes/Problems:Activity 3.1.1. Some phytotoxicity was observed on fruit while doing the trial. We\'ll have to redo the trial, reajust concentrations and application methods. What opportunities for training and professional development has the project provided?Training: Sadat Amankona, \"Optimization of organic apple storage\", Ph.D. in Horticulture. Aug 2022 - present. Professional Development One grower meeting to 25 apple growers. One summer intern conducting a survey to producers Tour and technical discussion. Hispanic Orchard Employee Education Program (HOEEP)- Wenatchee Valley College (39 attendees, 03/08/2023). How have the results been disseminated to communities of interest?Talks: Amiri. A. 202.2. Update on efficacy of numerous organic materials for postharvest rots control. WA State Fruit Association Annual Meeting, Wenatchee. Dec. 06, 2022. Amiri, A. 2023. Pre and postharvest disease management in organic apple systems. WA Apple Review Day. January 25, 2023. Amiri, A. 2023. Effective use of organic materials: preharvest for postharvest diseases. Organic Growers Meeting. Benton City, Feb. 15, 2023. Grower meeting, February 23rd. Columbia Basin Tree Fruit Club (25 attendees) Torres, C.A. 2023. \"Impact of hot weather on postharvest fruit quality in apple and pear\". ASHS Webinar Series (Feb. 8, 2023). Torres, C.A. 2023. Defectos de Pre-Post Cosecha en Manzanas Asociados a Altas Temperaturas en el Campo. G.S. Long Company, Inc. Grower Meeting, Yakima, WA (Jan 11, 2023). Martha Sanchez-Tamayo, Critzer, F. 2023. Technical presentation. \"Inactivation of Foodborne Pathogens on Apples through Application of Antimicrobial Waxes\" (ID# 31329) at International Association for Food Protection - IAFP - Annual Meeting. July 16-19, 2023. Toronto, Ontario, Canada. Martha Sanchez-Tamayo, Critzer, F. 2023. Departmental seminar. \"Inactivation of Foodborne Pathogens on Fruits by Application of Antimicrobial Coatings\". Spring Seminar Series. Department of Food Science and Technology. University of Georgia. February 28, 2023. What do you plan to do during the next reporting period to accomplish the goals?PD-Amiri: Objective 1: Activity 1.1. Conduct on farm assessment of new organic materials Objective 2: Activity 2.1.2. Repeat trials on efficacy of DCA in reducing postharvest decays Objective 2: Activity 2.2.1. Determine temperature thresholds on fruit and their efficacy in inhibiting spore germination Objective 3: Activity 3.1.1. Optimization of antimicrobial coating to fight postharvest decays. Co-PD Torres: Objective 2: Activity 2.2.1. Data analysis for season 2021-2022 and storage trial for 2022-2023. Fruit will be sourced from the same commercial blocks for Gala and Honeycrisp apples used the previous season. This execution of this activity will last 12 months. Objective 3: Activity 3.1.1. Fruit maturity, physiological disorders, and phytotoxicity will be evaluated at the time of treatment (oil-based coatings) and after 3 months of storage at 2°C. Co-PD Critzer: Sub-obj. 3.1. Activity 3.1.2. Evaluate coatings to control foodborne pathogens surrogates in long-term controlled atmosphere storage Sub-obj. 3.2. Activity 3.2.1. Sensory evaluation of antimicrobial waxes on Honeycrisp apples Co-PD Gallardo (Objective 4) Activity 1: Preliminary partial budget analysis of alternative preharvest schedule of

chemical sprays (using data from Obj. 1) to derive the net change in farm profit relative to standard practice. Activity 2: Preliminary partial budget analysis of CA and DCA (using data from Obj. 2) to derive the net change in farm profit relative to status quo storage protocols for organic Gala and organic Honeycrisp apples. Co-PD Sallato (Objective 5). Coordinate advisory board meeting (Nov 2023). Grower meeting coordination to deliver outcomes. Translation of outputs to Spanish Impacts What was accomplished under these goals? Objective 1: Conduct on-farm research to assess the efficacy of enhanced preharvest management practices to fight fungal infections and improve fruit quality in storage \Research\ Activity 1.1. On-farm assessment of new organic materials to implement a timely effective seasonal spray to mitigate fruit infections by field pathogens. \Amiri\. Trials were conducted in 2023 at two organic certified commercial orchards to assess the efficacy of preharvest sprays applied at different timings during the growing season. Trials were conducted on Honeycrisp and Fuji cultivars two of the major cultivars grown in WA. Fruit will be harvested from different treatments in September and October 2023 and will be stored in regular cold atmosphere. Fruit will be inspected for decay incidence and decay type for 6 to 8 months. Data will be available in 2024 and trials will be reconducted then. Activity 1.2. Effects of preharvest applications of organic ethylene blockers to extend the harvest window and postharvest quality in long-term storage.\Torres\. All applications and evaluations were done as planned. Major outcomes include: AVG - organic formulations (Retain®OL) were able to significantly delay fruit maturity (softening, de-greening, starch degradation and decrease in acidity) prior harvest and extend the harvest window. In general, all AVG treatments (different dose and times of application) were able to maintain higher firmness, less chlorophyll degradation, ethylene production and respiration rate until 9 months into cold storage (controlled atmosphere) compared to the untreated control, although not always statistically different at different evaluation time points, including the shelf-life period. Fruit condition varied upon treatments and time in storage. OBJECTIVE 2: Conduct lab- and postharvest-research to assess efficacy of non-chemical methods to improve quality and reduce fungal decays \Research\. Sub-objective 2.1. Activity 2.1.1. Effect of DCA on fruit quality and physiological disorders \Torres\. In 2022, fruit from 3 commercial blocks (2 Honeycrisp, 1 Gala) were harvested and stored in DCA (Dynamic Control Atmosphere), static controlled atmosphere, and regular atmosphere (air) at 3oC and 1oC, respectively. Fruit was stored for up to 9 months plus 4 weeks in air storage. Evaluations of fruit quality and condition are ongoing. Maturity progression in Honeycrisp from both commercial blocks (W42 and C802) showed that due to the growing season weather, particularly the cold spring and heat waves in June and July, increased fruit\'s maturity rate leading to high ethylene, softening rate and starch degradation at commercial harvest. Activity 2.1.2.-Efficacy of DCA against four major postharvest pathogens on artificially inoculated detached fruit (Year 1-2). \Amiri\. Organic apples harvested in October 2022 were inoculated with spore suspensions at 105 spores/ml of four major postharvest pathogens, i.e., Penicillium expansum, Botrytis cinerea, Phacidiopycnis washingtonensis and Mucor piriformis. Fruit were then stored under three storage conditions, i.e., regular atmosphere, static controlled atmosphere and dynamic controlled atmosphere. Four replicates of 25 fruit each were used for each pathogen and storage condition combination. Fruit will be inspected for decay incidence in August 2023 to mimic long-term storage. Sub-objective 2.2. Activity 2.2.1 Optimal temperatures for apple cultivars \Amiri\. Seven of the most grown cultivars in WA were tested at 5 different temperatures, i.e., room temperature, 48, 49, 50 and 52C for 1 or 2 min to assess temperature thresholds. Preliminary results showed that all cultivars did not show any visible damage when treated at temperatures up to 51C, whereas 2 cultivars showed slight surface browning when treated at 52C. Internal fruit quality is being assessed to evaluate the effect of different temperatures on fruit quality. The same temperatures and exposure times have been tested against 2 major pathogens decaying pome fruit to assess kill-threshold for each pathogen. Work is ongoing to test 3 additional pathogens in vitro. Activity 2.2.2. Efficacy of thermotherapy to reduce postharvest decay \Amiri\. Organic fruit from the cultivar Fuji have been inoculated with spore suspensions of Penicillium expansum, Botrytis cinerea, Phacidiopycnis washingtonensis or Mucor piriformis and incubated for 24 hrs at room temperature. Fruit were then dipped in water at room temperature or in water heated to 50 and 51C. Fruit were incubated at 1C in regular atmosphere and are awaiting inspection for decay incidence. OBJECTIVE 3: Assess the efficacy of postharvest organic antimicrobial coatings to mitigate microbial and fungal contaminations in organic fruit Activity 3.1.1. \Amiri\. Four microbial organic coatings have been tested on detached fruit for their efficacy to reduce storage infection to fungal pathogens. Fruit were stored in regular cold storage and inspected monthly for decay development. There were differences in coatings efficacy but some phytotoxicity was observed on fruit with some of coastings as well. Activity 3.1.2 Evaluation of coatings to control foodborne pathogen surrogates in long term storage \Critzer\ Sub-obj. 3.1. Efficacy of antimicrobial coatings applied at harvest to protect from fungal contaminants in long term storage Gala apples Inactivation of L. monocytogenes on organic Gala apples by application of antimicrobial waxes Inactivation of Salmonella on organic Gala apples by application of antimicrobial waxes 3. Inactivation of E. coli O157:H7 on organic Gala apples by application of antimicrobial waxes 4. Sensory evaluation. A sensory discrimination test was used to identify differences between waxed apples for treatments with the greatest efficacy High-level findings: Carnauba wax containing 2% EOs was the most effective treatment for inactivating target foodborne pathogens inoculated on apples for 40 days. This treatment showed 4.05, 1.38, and 2.81 Log CFU/apple reduction in L. monocytogenes, E. coli O157:H7, and

Salmonella, respectively, compared to uncoated apples. Carnauba wax containing 2% EOs showed significantly (P\<0.001) lower populations of L. monocytogenes and Salmonella compared with 1% EOs, 0.5% cultured dextrose, or wax-only control. In contrast, there were no significant differences (P\>0.05) for E. coli O157:H7. Sensory evaluation showed that panelists could detect differences for apples treated with wax containing 2% EOs, but not for 1% EOs compared to wax-only control. Some panelists associated sweet, floral, spiced, and tropical smells as the dominant odors for these samples but did not necessarily find them unpleasant. Honeycrisp apples Inactivation of L. monocytogenes on organic Honeycrisp apples by application of antimicrobial waxes Inactivation of E. coli O157:H7 on organic Honeycrisp apples by application of antimicrobial waxes (in progress - Ends July 2023) OBJECTIVE 4: Economic analysis. Data about returns and costs of production have been collected for organic Gala and organic Honeycrisp. These data are used to develop the enterprise budgets. \Gallardo\. Enterprise budgets for organic Gala and organic Honeycrisp based on industry standard have been updated and published. These will be used as baseline for the economic analysis of the alternatives of preharvest schedule of sprays and postharvest CA and DCA storage treatments to reduce decay and disorders. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Amiri A., Fomba J. 2022. In vitro activity of several organic materials against major postharvest pathogens. Phytopathology 112-11-S3:116 Type: Other Status: Published Year Published: 2022 Citation: \" Gallardo, R.K. and S.P. Galinato. 2022 Cost Estimates of Establishing, Producing and Packing Organic Gala Apples in Washington. Washington State University Extension Publication TB19E. Type: Other Status: Published Year Published: 2022 Citation: \" Gallardo, R.K. and S.P. Galinato. 2022 Cost Estimates of Establishing, Producing and Packing Organic Honeycrisp Apples in Washington. Washington State University Extension Publication TB91E. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:Our main audience were organic apple growers and packers. Efforts included: 1-Research: PD-Amiri and Co-PD Torres have worked closely with organic growers and packers to conduct activities planned in Objectives 1 and 2. 2-Outreach and education: A. The team held an Advisory Board meeting in July 2022 to discuss project findings and receive feedback. B. CO-PD Gallardo has reached out to several organic growers to collect data about returns and costs of production for organic Gala and organic Honeycrisp. These data will be used to develop the enterprise budgets. C. Co-PD Sallato conducted a baseline survey of organic apple growers and results were shared with Advisory board members. Changes/Problems:Changes None currently Problems 1-Copping with weather conditions: Severe weather conditions, i.e., snow and freezing temperatures, which occurred just at the bloom period had disastrous consequences on many growers including our collaborators which impacted and delayed some activities in Objective 1. 2-Hiring skilled workers and students. The Covid-19 pandemic has reduced our ability to hire skilled employees and limited student hires, especially international students. 3-Obtaining needed information from stakeholders: Objective 4. Economic assessment The main challenge for the economics study is identifying and reaching out to sources of data for the economic analysis, i.e., meet with at least two organic Gala and organic Honeycrisp growers to validate assumptions and estimates, meet with packinghouse representatives. To address this challenge, we will request from project team members a referral to these stakeholders whom they are working with currently or they have collaborated in their previous projects. What opportunities for training and professional development has the project provided?Training: 1- Janis Fomba, a Scientific Assistant in the Plant pathology program (PD-Amiri) was trained in postharvest pathology and organic decay management. 2- Martha Tamayo, a Postdoctoral Scientist in the Food Science program (co-PD Critzer) was trained in foodborne and food safety issues of pome fruit. Professional Development Janis Fomba attended the 2022 Annual American Phytopathological Society (Plant Health) in Pittsburgh, PA and presented a poster summarizing some of the results from this project. How have the results been disseminated to communities of interest?Workshop: PD Amiri organized a webinar on organic decay management in March 2022 attended by 110 people. Talks: PD Amiri A gave a talk: Update on efficacy of organic materials and research needs to minimize decay at theWA Tree Fruit Association Annual meeting. Dec 7th, 2021, attended by 130 stakeholders. Co-PD Torres gave a talk at the 10th Annual Pace Postharvest Academy, \"Storage Technologies for organic apples,\" Pace International LLC, Clee Elum, United States of America. (May 4, 2022). What do you plan to do during the next reporting period to accomplish the goals?PD-Amiri: Objective 1: Activity 1.1. Conduct on farm assessment of new organic materials Objective 2: Activity 2.1.2. Repeat trials on efficacy of DCA in reducing postharvest decays Objective 2: Activity 2.2.1. Determine temperature thresholds on fruit and their efficacy in inhibiting spore germination Objective 3: Activity 3.1.1. Optimization of antimicrobial coating to fight postharvest decays. Co-PD Torres: Objective 1: Activity 1.2. Repeat preharvest sprays of organic materials to block ethylene Objective 2: Activity 2.2.1. Effect of DCA on fruit quality Objective 3: Activity 3.1.1. Efficacy of antimicrobial coating in extending shelf life of organic apples. Co-PD Critzer: Sub-obj. 3.1. Efficacy of antimicrobial coatings applied at harvest to protect fungal and human pathogens in long-term storage Activity 3.1.2. Evaluation of coatings to control foodborne pathogen surrogates in long-term controlled atmosphere storage Co-PD Gallardo (Objective 4) We will finalize the organic Gala and organic Honeycrisp enterprise budgets. We will also collect data for the partial budget analysis of alternative practices in pre-harvest spraying and in storage to mitigate decay and disorder incidence. Co-PD Sallato (Ojective 5) Co-PD Sallato and all team members will present preliminary findings at grower meetings in

WA. **Impacts** What was accomplished under these goals? Impacts: Research findings from this project will impact organic growers and packers in Washington which provide nearly 100% of organic apples to the U.S. consumers. Findings will impact organic apple growers and packers in any other growing regions. This cross-disciplinary project will impact the way organic fruit are grown and stored. This includes empowering organic growers to protect fruit from fungal infections and allow organic packers reduce fruit loss due to postharvest decay significantly. Research proposed herein will also develop solutions to help organic growers and packers to enhance fruit quality (horticultural practices) and extend shelf life of organic apples while reducing physiological disorders. Teh food safety part of the project will help organic packers eliminate foodborne bacterial contaminations in organic apples. Accomplished activities in 2021-2022 period: Objective 1: Conduct on-farm research to assess the efficacy of enhanced preharvest management practices to fight fungal infections and improve fruit quality in storage \Research\ Activity 1.1. On-farm assessment of new organic materials to implement a timely effective seasonal spray to mitigate fruit infections by field pathogens. This activity was not conducted in 2022 at organic commercial farms because of severe weather conditions of snow and freezing temperatures which occurred in main production areas of WA state during the bloom period. This had severe consequences on yield. The collaborating growers preferred to postpone this activity to the next season. Activity 1.2. Effects of preharvest applications of organic ethylene blockers to extend the harvest window and postharvest quality in long-term storage. Organic formulation of aminoethoxyvinylglycine (AVG, Retain®OL) was applied at two different rates 166 and 333 gal/ac at three preharvest timings, i.e., 21, 7, and 3 days preharvest (dph) in August 2021 at aa organically certified commercial orchard. Maturity progression was determined using maturity indices (skin color, starch degradation, ethylene production, respiration rate, soluble solids, fruit weight) weekly starting approximately one week before first treatment application. Results: Retain®OL applications were able delay chlorophyll degradation, starch degradation, and softening rate preharvest in a dose and timing-dependent manner. Postharvest evaluations were recently finished, and data are being analyzed. OBJECTIVE 2: Conduct lab- and postharvest-research to assess efficacy of non-chemical methods to improve quality and reduce fungal decays \Research\. Activity 2.1.2.1-Efficacy of DCA against four major postharvest pathogens on artificially inoculated detached fruit (Year 1-2). Fuji apples were inoculated with 10\^5 spores/ ml ofB. cinerea, Neofabraea perennans 15 days preharvest or with P. expansum and M. piriformis at commercial maturity. Fruit were stored at 3 different atmospheres, i.e., regular atmosphere (21% O2), Controlled Atmosphere (CA: 4%O2 & 1% CO2), or Dynamic controlled atmosphere (DCA: 0.5 to 0.7% O2, 0.7 to 1% CO2) for up to 6 months. Preliminary results show that DCA reduces decay incidence by 5 to 10% more compared to CA. Experiments will be conducted again in 2022. OBJECTIVE 3: Assess the efficacy of postharvest organic antimicrobial coatings to mitigate microbial and fungal contaminations in organic fruit Sub-obj. 3.2. Efficacy of antimicrobial waxes applied during packing that can be used to protect against foodborne pathogens during distribution to the consumer. 3.2.1. Optimization of carnauba wax to inactivate human foodborne pathogens. Organic Gala apples from WA were treated 2 Carnauba wax concentrations in combination with 4 antimicrobial essential oils and inoculated with Listeria monocytogenes (548-072, ATCC 19115 4b, 19111, Scott A, 1/2a), Salmonella (Gaminara, Montevideo, Newport, St. Paul, Agona), or Shiga-toxigenic Escherichia coli to test for their survival on apple fruit. 1- Survival of Listeria monocytogenes on organic Gala apples. Carnauba wax with 2% EOs significantly decreased (P<0.05) the population of L. monocytogenes during storage at 20°C compared to the other target formulations. After day 30 of storage, no significant differences were found in the L. monocytogenes population for apples treated with carnauba wax with 1% EOs, 0.5% EOs or MicroGARD and apples treated only with carnauba wax. At the end of storage, the population of L. monocytogenes on apples coated with 2% of essential oils was decreased by 1.82 and 4.05 Log CFU/Apple compared with wax treatment only and control treatment (untreated) respectively. L. monocytogenes can survive on the surface of untreated apples over 40 days of commercial retail storage conditions (20°C). 2. Survival of Salmonella on organic Gala apples. Carnauba wax with antimicrobials (2% EOs, 1%EOs, and MicroGARD) significantly decrease (P<0.05) the Salmonella population in apples compared to controls (wax only and no treatment). Carnauba wax with 2% EOs achieves the greatest decrease in the Salmonella population in apples during 14 days of storage at 20°C OBJECTIVE 4: Economic analysis. Data about returns and costs of production have been collected for organic Gala and organic Honeycrisp. These data are used to develop the enterprise budgets. OBJECTIVE 5: Develop and deliver outreach activities to organic stakeholders \Extension\. A team meeting was organized in May 2022, and an Advisory board meeting in July 2022. We conducted a base line survey to organic apple growers. **Publications** - Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2022 Citation: Achour A. and Fomba J. 2022. Efficacy of organic materials against several postharvest pathogens of pome fruit. Abstract. Phytopathology. Accepted

↑ Return to Index

Finding Common Ground - Merging Tribal Life Ways with Modern Organic Agriculture Practices

Accession No.	1026670
Project No.	WIS04043
Agency	NIFA WIS\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34898
Proposal No.	2021-02945
Start Date	01 SEP 2021
Term Date	31 AUG 2022
Grant Amount	$49,254
Grant Year	2021
Investigator(s)	SILVA, E. M.; Tracy, WI, F.
Performing Institution	UNIV OF WISCONSIN, 21 N PARK ST STE 6401, MADISON, WISCONSIN 53715-1218

NON-TECHNICAL SUMMARY

Indigenous food systems are increasingly recognized as critical components to supporting the health and cultural continuance of Indigenous communities. Many Tribes across the US are making marked progress toward building more self-reliant food system economies that focus on the production of organic food and products to feed their communities. To continue to support the ongoing growth of Tribal food sovereignty and food production initiatives, particularly in the context of organic production, we propose to bring together a working group of Tribal community leaders and University/Extension faculty and staff of each of the 1862 and 1994 Land Grant Colleges and Universities in the state of Wisconsin. Working closely with Tribal community members and Land Grant College and University faculty and staff, the goals of this planning proposal are 1) to conduct a needs assessment and compile asset and resource map that will contribute to the development of a white paper outlining a roadmap of activities that will support Tribal agriculture programs and education, particularly in the context of organic agriculture, and 2) to become better acquainted with one another across cultures and the landscape. Through project activities, we will gain clearer understanding of Tribal needs, developing holistic, community-based strategies to strengthen and expand the production of organic food by building strong relationships and trust. Successful completion of this planning process will result in the formation of an expanded ongoing UW-Madison/Native Nations Agriculture Working Group and submission of integrated multiregional proposal(s). This projects meets OREI goals 1, 2, 5, and 7.

OBJECTIVES

Working closely with Tribal community members and Land Grant College and University faculty and staff, the goals of this planning proposal are 1) to conduct a needs assessment and compile asset and resource map that will contribute to the development of a white paper outlining a roadmap of activities that will support Tribal agriculture programs and education, particularly in the context of organic agriculture, and 2) to become better acquainted with one another across cultures and the landscape. Through project activities, we will gain clearer understanding of Tribal needs with respect to food production, sovereignty, and education, developing holistic, community-based strategies to strengthen and expand the production of organic food by building strong relationships and trust. Successful completion of this planning process will result in the formation of an expanded

ongoing UW-Madison/Native Nations Agriculture Working Group and submission of integrated multiregional proposal(s) to USDA-NIFA and other programs.

APPROACH

Methods include the following: 1\) Community-based meetings of working group members and other stakeholders involved in Tribal food sovereignty and food systems efforts as well as follow-up individual interviews will occur in the summer and fall throughout 2021 and 2022. Four events will be held over the course of the project at sites highlighting current projects, including within Tribal communities and at the 1862 and 1994 Land Grant partners. The project manager/outreach specialist, along with local Tribal community hosts, will be prepared to facilitate the meeting, and related discussion, incorporating knowledge gained from Objective 1. These facilitators will provide a brief introduction of the goals of the meeting, the ground rules, a summary of activities to date to serve as an introduction to the day-long meeting, and instructions to obtain consent from participants. The meeting participants will then convene in small group, responding to 8-10 open-ended questions; facilitators will ensure all participants respond, drawing out members when necessary, and politely closing off dominant participants if required (Groves et al., 2004). Following the discussion, community-based workshops will be offered to engage community members around topics such as reducing tillage, soil health, and seed saving in organic systems 2\) We will use a combination of written assessment tools as well as information gathered from in-person listening sessions. We will identify areas of need that are limiting the progress and expansion of Tribal food sovereignty efforts, including aspects related to organic food production, processing, and education. Additionally, we will identify other areas that could benefit from partnerships across the working group members and other public agencies, including access to federal agriculture programs, business management, undergraduate education, and Extension. 3\) The project manager, with the PDs and working group members, will summarize the outcomes of the needs assessment, asset and resource mapping, and listening sessions into a white paper, which also proposes a roadmap forward as to how the project partners and other public agencies can work together in the future to support Tribal food sovereignty goals and related education efforts. Approximately ten stakeholders from the working group will be more intimately involved in the development of the white paper and future research proposals for submission to the OREI, AFRI, and other USDA programs. Progress 09/01/21 to 08/31/23 Outputs Target Audience:Tribal farmers; UW-Madison and UW-Extension faculty, staff, and students; Tribal agriculture leaders; Tribal Nation community members Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?We held five workshops across the state that provided training for Tribal ag leaders, UW researchers and students, and Tribal farmers. These workshops included topics related to: maple sugaring; UW agricultural research station tour featuring research related to indigenous systems; Regenerative Indigenous Agriculture Tour to three Tribal partner sites; an \"CALS/Tribal Nations Workshop\"; and a pre-conference event held prior to the Marbleseed Conference, \"Farm to Community Wellness: Networking Local Food Supply Chains\". These events not only contributed to professional development, but also as events to host listening sessions contributing to our needs assessment. How have the results been disseminated to communities of interest?We have disseminated the results through meetings, field days, and a final report, including a map of current activities related to Tribal food systems and food sovereignty in the upper Midwest. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Our planning team conducted a needs assessment related to the expansion of Tribal food systems and agriculture projects. A core team met monthly throughout the duration of this project. To obtain perspectives outside of the core team, we also organized listening sessions and workshops to reach out to a broader range of Tribal community members. These activities occurred in conjunction with field days and workshops in the summer of 2022. We further coordinated information gathering sessions related to activities occurring at the Marbleseed conference in 2023 as well as the Great Lakes Intertribal Food Council meetings. These results were summarized and incorporated into a Kumu map, as well as a white paper that was used as the basis for a USDA Sustainable Agriculture Systems grant proposal. This project was successful in its objectives to build stronger relationships between statewide Tribal partners and UW-Madison. This project has resulted in the creation of a UW-Madison College of Agriculture and Life Sciences Tribal Agriculture Working Group to better facilitate activities across projects and with Tribal Nations. This project also contributed to the successful funding of two graduate students and one FTE coordinator with investment from college funding. Publications Progress 09/01/21 to 08/31/22 Outputs Target Audience:UW-Madison and UW-Extension faculty, staff, and students Tribal agriculture leaders Tribal Nation community members Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?We held five workshops across the state that provided training for Tribal ag leaders, UW researchers and students, and Tribal farmers. How have the results been disseminated to communities of interest?We have disseminated the results through meetings, field days, and a final report, including a map of current activities related to Tribal food systems and food sovereignty in the upper Midwest. What do you plan to do during the next reporting period to accomplish the goals?We have completed the project as of the end of this

reporting period. Based upon the information generated from this project, we applied for and were awarded a USDA Sustainable Agricultural Systems grant. Impacts What was accomplished under these goals? Our planning team will conduct a needs assessment related to the expansion of Tribal food systems and agriculture projects. A core team met monthly throughout the duration of this project. To obtain perspectives outside of the core team, we also organized listening sessions and workshops to reach out to a broader range of Tribal community members. These activities occurred in conjunction with field days an workshops in the summer of 2022. We further coordinated information gathering sessions related to activities occurring at the Marbleseed conference in 2023 as well as the Great Lakes Intertribal Food Council meetings. These results were summarized and incorporated into a Kumu map, as well as a white paper that was used as the basis for a USDA Sustainable Agriculture Systems grant proposal. This project was successful in its objectives to build stronger relationships between statewide Tribal partners and UW-Madison. This project has resulted in the creation of a UW-Madison College of Agriculture and Life Sciences Tribal Agriculture Working Group to better facilitate activities across projects and with Tribal Nations. Publications

↑ Return to Index

Creation of Regional and Local Maize Food Systems (products Integrating Breeders, Growers, Supply Chains and End Users)

Accession No.	1026715
Project No.	WIS04044
Agency	NIFA WIS\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51300-34912
Proposal No.	2021-02935
Start Date	01 AUG 2021
Term Date	31 JUL 2022
Grant Amount	$42,749
Grant Year	2021
Investigator(s)	Tracy, W. F.
Performing Institution	UNIV OF WISCONSIN, 21 N PARK ST STE 6401, MADISON, WISCONSIN 53715-1218

NON-TECHNICAL SUMMARY

We propose a series of online planning grant sessions that will lead to a full OREI proposal in 2022, as well as additional research and networking to identify and document those who are disparately working on specialty maize breeding, maize variety conservation, maize culinary preservation/perpetuation/promotion, and maize culinary innovation. We define culinary maize as maize specifically selected for its organoleptic and food qualities. The goal of the planning sessions is to bring together stakeholders from throughout the organic culinary maize value chain in order to identify opportunities and challenges for expanded production of organic, value-added food maize. Our long-term goal is to provide organic growers, end-users and consumers with nutritious, high-value maize and systems that are economically rewarding and sustainable. Currently, organic culinary maize production is challenged by limited information about the best varieties, availability of quality seed, production best practices, including appropriate equipment for small and medium scale diversified growers and inadequate networking among growers and end-users. The burgeoning local tortilleria scene, along with growing immigrant populations and a renaissance of indigenous First Nation foodways in many parts of the country means that demand for culinary maize is growing - with much of this demand currently being met with imported maize. Likewise, a revival of Southern Foodways including products like hominy, grits, and cornbread creates specific regional market opportunities. In many parts of the country polenta is better known than ever, though infrequently locally produced. Innovative uses of maize - such as in miso and other fermented products are in their infancy. Other relatively obscure (in the US) types of fresh maizes, (tender kernel) elotes, chocleros, and waxy corn remain to be adapted and enhanced. Sweet corn designed for raw consumption like a banana offers new opportunities. All of the above beg for the creation of regional and local maize food systems which link present and potential organic producers with creative end users, the majority of whom desire organically produced maize for their products. To understand such systems and make them viable, we also propose to investigate the economics and potential supply chains including identity preservation and storage.

OBJECTIVES

Maize is presently a dominant part of American agriculture and, indirectly, a significant part of the American diet. There are well-documented environmental and public health problems with large scale, conventional maize

monoculture. There are also valid critiques at the role of maize products in processed foods that have contributed to the many health crises faced presently in the United States. Due to these issues, maize is often demonized in sustainable agriculture and health-oriented circles (i.e. in the writings of Michael Pollan and the film King Corn). This project seeks to clarify that maize itself is not to blame for these issues and that, in actuality, the species can play an extremely important role in productive, sustainable agricultural systems and healthy diets. To fulfill this promise, the diversity of maize needs to be better explored, grown, promoted, and made available to end users and consumers. Many heirloom varieties are well adapted to organic agriculture through selection by farmers before chemical fertilizers were available and the fact that as open pollinated populations there is still enormous variation that can be further selected for specific environments. Many of these heirlooms were for human consumption and have specific culinary qualities including multiple culinary uses from the same variety. Market opportunities for farmers from cultural groups for whom maize is significant should be expanded and access to maize based products expanded for these populations, as well as American eaters more broadly. There is work being carried out towards such goals but at present efforts are fractured and/or discipline bound. We seek to create a vibrant, well-connected community of researchers, growers, and end-users to increase the market for culinary corns in the US.

APPROACH

The planning grant proposal grew out of a recognition among collaborators and stakeholders of the growing interest in culinary corns and the lack of national or regional efforts to coordinate the development of regionally based maize food systems by creating opportunities for collaboration among researchers, breeders, germplasm curators, growers and the myriad of end users. Having witnessed and participated in similar work with other crops, it was felt that a concerted effort focussed on culinary corns could help organize the many stakeholders and move such work forwards. By bringing together these stakeholders, both unique regional issues and broader national issues and opportunities can be identified that could inform a full OREI proposal. The first planning grant session is planned for June 2021 via Zoom, followed by in person or on-line regional hub meetings, according to COVID situation at the time. Two subsequent on-line meetings will be held. These will be scheduled to ensure sufficient opportunity to compile outcomes, assign responsibilities, and prepare a full proposal for submission in 2022. In this planning grant, we propose to develop a plan for a full OREI proposal, via in-depth discussion and engagement with key research, producer, and end-user stakeholders over the months of the meetings. The full proposal will focus on strengthening public sector value-added culinary corn research with the long-term goals of ensuring the availability and utilization of genetic resources and stimulating economic development by strengthening local production and consumption of culinary corns, identifying agronomic, genetic, and marketing gaps in need of attention. The following topics and a preliminary set of discussion points will be addressed in the initial planning sessions - one among principal collaborators and one in each region. National and regional germplasm resources, Market demand, Economics, Crop protection, Foods, and Outreach. The meeting format will include presentations from key stakeholders to be identified and recruited. The day will begin with introductions by attendees followed by setting the stage with an explanation of the rationale for bringing stakeholders together to investigate a formal collaboration and the vision and potential for organic culinary corns. **Progress** 08/01/21 to 09/30/22 **Outputs** Target Audience:Audiences: Indigenous growers, organic farmers, backyard gardeners, seed preservation organizations, foodways preservation societies, crop conservation specialists, crop breeders, millers, masa makers, restaurateurs, food truck operators, and consumers. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? We have spent additional time to consider ways to include Native Peoples in ways that foster connection and communication while leaving autonomy for their independent decision making within the project. In fact, we have decided to take extra time this year to start some pilot projects to experiment with the logistics required to provide the seed, grain storage, and evaluation capacity needed to create an impact. How have the results been disseminated to communities of interest? Seed of historic culinary varieties have been shared with farmers of the Lumbee tribe to help start culinary projects for the tribe, in an evolving collaboration. Seed was also shared with an African American farmer in North Carolina who is producing seed for himself and for distribution to other farmers who will participate in the next year. A grain storage workshop was held with the Pawnee Tribe of Oklahoma with a Grain Pro representative to provide an opportunity to see if hermetic storage technology would be helpful for their needs. We also provided funding for a culinary event with decision making about the scope, objectives and timing left to tribal members as a pilot exploration into Indigenous autonomy while participating in a larger project. Large increases of grain have been accomplished in Madison, Wisconsin to enable multiple chefs to simultaneously evaluate and exchange information on a small set of varieties. The mechanics of the exchange of evaluations among chefs is being worked out through this pilot project. In the Pacific Northwest, there is an exchange of information on variety performance between a group of farmers and researchers to identify suitable varieties. These materials are also being shared with chefs to begin the process of evaluation. All these experiences are pilot projects informative to the full proposal to enable a larger project to

be scaled effectively. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? PROGRESS: 2021/08 TO 2022/07 Target Audience: key players in culinary corn (breeders, collection curators, ancestral seed keepers, growers, extensionists, millers, tortilla makers, chefs, and culinary influencers), Our work began with the creation of a survey that was sent to individuals identified for invitations to planning meetings to evaluate interest levels, concerns and needs. The survey received 55 responses, mainly from the Midwest (32.7%) and Southeast with 32.7%, Pacific Northwest participants were 16.4 % and other areas participating were Northeast, Upper Midwest, Hawaii, and Arizona. The highest participation was from present maize growers (38.2%); maize processors (36.4%); consumers (32.7%); and researchers (30.9%). Constraints that growers face were animal predation, availability of well adapted varieties, availability of marketable varieties, harvesting equipment, post-harvest handling and storage, all cited by 48.1% of participants, access to markets (44.4%) and weed competitiveness/cultivation (37%). Most needed interventions were screening new varieties and development of equipment 58.5% each. Selection work with existing varieties, and breeding of new varieties 56.1% and consumer education 53.7%. The types of maize that participants said they wished they had access to were: Blue Dent 54.3%, Large Kernelled 42.9%, Blue Flint and Red Dent 37.1% We conducted five on-line planning grant meetings, initiating with a meeting of Nation Committee Members (representing the target regions and the breadth of the project) held on June 28th, 2021. In total there were 95 attendees to the on-line planning meetings, a portion were attendees in multiple meetings. Regional Meetings were held in the Pacific Northwest (date?), South (Sept 16th, 2021), and Great Lakes Regions Oct. 5th, 2021) (minutes, and recordings are available as Annexes.) We concluded with a meeting of the National Committee Members on Nov. 16th, 2021, to review the outcomes of the regional meetings and surveys. We formed working groups, and the principal investigators began discussions of the proposal. We had a strong concern to appropriately integrate Native Seedkeepers and Indigenous Food sovereignty efforts, since culinary corn is based on First Nations maize varieties. **Publications** ORG Transitions{.underline}

↑ Return to Index