

# OREI Project Details

## Award Year 2017

16 Research Projects

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# Organic Agriculture Soil Health Research Symposium

<b>Accession No.</b>	1013137
<b>Project No.</b>	CALW-2017-02444
<b>Agency</b>	NIFA CALW\
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26851
<b>Proposal No.</b>	2017-02444
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2018
<b>Grant Amount</b>	\$41,759
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Jenkins, D.; Treadwell, DA, D.; Mesh, MA, G..
<b>Performing Institution</b>	ORGANIC FARMING RESEARCH FOUNDATION, 303 POTRERO ST STE 29-203, SANTA CRUZ, CALIFORNIA 950602759

## NON-TECHNICAL SUMMARY

The Organic Agriculture Soil Health Research Symposium (OASHR) will bring together researchers, educators, extension personnel, industry leaders, farmers, and ranchers, and others to report on current research results in improving organic agriculture, identify research, education or extension needs, update educational information, and advance the understanding of organic issues and problems using a systems-based approach related to soil health. Research on organic agriculture is providing researchers and farmers with much needed information to increase sustainability and support the economic growth of what is currently the fastest growing production systems in U.S. agriculture. (USDA, 2016). The OASHR will provide current information valuable to researchers and end-users as a Special Session held in conjunction with the Tri-Societies meeting. Many researchers working on conventional systems are looking for links to organic methods that can enhance a range of production systems. Graduate and under-graduate students need to be informed of the organic research efforts in consideration of educational and career goals. Continuous improvement in organic farming systems and technology transfer requires making the latest results of research accessible to a broad disciplinary spectrum of researchers, farmers, and other practitioners.

## OBJECTIVES

The 2017 Organic Agriculture Soil Health Research Symposium (OASHR) will be held in Tampa, Florida on October 25, 2017 as a Special Session in conjunction with the 2017 Tri-Societies meeting. The symposium will focus on research presentations, research needs panel discussion, and poster session. Based on OFRF feedback from producers and researchers, soil health is the highest priority for research. OASHR is on Soil Health and Soil Management research. The symposium will allow researchers to learn about current organic research results, peer interaction, and identification of future research needs. The symposium will be national and international in scope, and interdisciplinary with an additional focus on the southern US region. Outreach will be to students to learn about organic research and potential for education in organic agriculture. Researchers, educators, and extension personnel will be invited to submit. Advisory and Program committees will peer review abstracts for highest quality. The venue will be structured to facilitate interaction and discussions with farmers and other interested parties. Funding is requested to cover the expenses to organize and manage the symposium, and to cover expenses for farmer collaborators, students and researchers who have limited travel

budgets. Sessions will be live streamed and archived via b, and a post symposium webinar. Proceedings will be made publicly accessible on-line. A survey will be sent to participants to evaluate its impact. This project responds to the legislative goal of: Facilitating the development and improvement of organic agriculture production, breeding, and processing methods and 2017 OREI RFA priority 1.

## APPROACH

The symposium will be held in conjunction with the annual Tri-Societies (The Agronomy Society, Crop Society, and Soil Science Society of America) meeting in Tampa, Florida on October 25, 2017. The meeting anticipates over 4,000 scientists, professionals, educators, and students will attend the 2017 meeting with a theme of "Managing Global Resources for a Secure Future." Within the Tri-Societies, the Agronomy Society of America (ASA) also has the Organic Management Systems as an ASA Community within the Agronomic Production Systems Section and the Soil Science Society has the Soil Health Community. Both groups will participate in the activities of the symposium. The event will be promoted nationally and internationally. The Tri-Societies offers a major venue for researchers, farmers, and the public on sustainable and organic agriculture in the U.S. and internationally. OFRF staff will work with the Tri-Societies, the University of Florida, and Florida A&M University in planning and program development activities. The Project Directors will help with outreach to researchers, Extension, and agricultural professionals. Florida Organic Growers and Consumers (FOG) will assist in the coordination of regional and national organizations such as NSAC, ATTRA, state organic associations, and others to perform outreach to researchers and farmers. OFRF is a partner with the Soil Health Institute, which will provide additional national outreach. The symposium will include participant interviews and publication of proceedings on eOrganic.info.

## PROGRESS

2017/09 TO 2019/08 Target Audience: The recorded webinar at the Tri-Societies meeting remains active on the eOrganic site and has received over 1,000 views. Post session meetings with extension and students provided information for their resource use and encouragement to study and do research related to organic agriculture. Presentations and handouts were provided at the conferences. Power point slides and supporting materials remain available on the eOrganic website, OFRF website, and were sent to conference leadership and other supporting organizations for dissemination. There is a page on the eOrganic website, <https://articles.extension.org/pages/74555>, that describes the symposium and links to all the recordings which are on YouTube as a playlist. The link to the YouTube playlist is: [https://www.youtube.com/watch?reload=9&v=PorE-2cu9OY&list=PLZMuQJAj6rOp\\_vKfHasJQ1WaVHJaK3PKLz](https://www.youtube.com/watch?reload=9&v=PorE-2cu9OY&list=PLZMuQJAj6rOp_vKfHasJQ1WaVHJaK3PKLz) Views for each of the 8 videos can be seen by clicking on each video. The first one has had 673 views. 256 people registered for the live webinar and 120 attended. Demographics of the participants are attached in the appendix as well as the evaluation report. The conference presentations at the Tri-Societies symposium continue to receive views. A Proceedings has been written on the results of the Tri-Society conference, including the presentations at the symposium and individual presentation throughout different sessions at the conference. This report is located on the OFRF website. All of these documents are attached in the Appendix of this report for use by USDA. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Each conference presented to different primary audiences. The Tri-Society and American Horticultural Society attendees were composed of researchers, educators, crop advisors, and students. Continuing education credits were provided at the Tri-Society meeting. The SSAWG attendees were predominately farmers, ranchers, crop advisors and students. NSAC attendees were composed of policy advocates, NGOs, and other agricultural farmer representatives. The diversity of these conferences allowed presentations and workshops to be appropriate for understanding research results and adoption of research recommendations. Above all, a better understanding of organic agriculture and management options was provided. How have the results been disseminated to communities of interest? Presentations and handouts were provided at the conferences. Power point slides and supporting materials remain available on the eOrganic website, OFRF website, and were sent to conference leadership and other supporting organizations for dissemination. There is a page on the eOrganic website, <https://articles.extension.org/pages/74555>, that describes the symposium and links to all the recordings which are on YouTube as a playlist. The link to the YouTube playlist is: [https://www.youtube.com/watch?reload=9&v=PorE-2cu9OY&list=PLZMuQJAj6rOp\\_vKfHasJQ1WaVHJaK3PKLz](https://www.youtube.com/watch?reload=9&v=PorE-2cu9OY&list=PLZMuQJAj6rOp_vKfHasJQ1WaVHJaK3PKLz) Views for each of the 8 videos can be seen by clicking on each video. The first one has had 673 views. 256 people registered for the live webinar and 120 attended. Demographics of the participants are attached in the appendix as well as the evaluation report. The conference presentations at the Tri-Societies symposium continue to receive views. A Proceedings has been written on the results of the Tri-Society conference, including the presentations at the symposium and individual presentation throughout different sessions at the conference. This

report is located on the OFRF website. All of these documents are attached in the Appendix of this report for use by USDA. What do you plan to do during the next reporting period to accomplish the goals? All goals have been accomplished. This is the final report.

## IMPACT

2017/09 TO 2019/08 What was accomplished under these goals? Two national and two regional conferences provided for presentations and workshops on organic agriculture and soil health. In the post conferences surveys, the majority of attendees felt that their understanding or current organic research results and soil health practices related to organic production methods was improved and transfer of this knowledge to producers and students would be valuable and adoptable. The recorded webinar at the Tri-Societies meeting remains active on the eOrganic site and has received over 1,000 views. Post session meetings with extension and students provided information for their resource use and encouragement to study and do research related to organic agriculture. Conference Presentations: Agronomy, Crop, and Soil Science Societies, October, 2017, Tampa, FL The 2017 Organic Agriculture Soil Health Research Symposium (OASHR) will be held in Tampa, Florida on October 25, 2017 as a Special Session in conjunction with the 2017 Tri-Societies meeting. The Special Session was presented in conjunction with co-sponsors Organic Management Systems Community and Soil Health Community. The symposium focused on research presentations, research needs discussion, and poster session. Based on OFRF feedback from producers and researchers, soil health is the highest propriety for research. The symposium allowed researchers to learn about current organic research results, peer interaction, and identification of future research needs. Nine issues were identified--ranging from the effects of cover crops, compost, and rotation--to the influence of soil management practices on economic returns and best ways to disseminate information to producers. The symposium was national and international in scope, and interdisciplinary with an additional focus on the southern US region. Outreach supported students to learn about organic research and the potential for education in organic agriculture. Researchers, educators, and extension personal were invited to submit abstracts for presentations. Advisory and Program committees peer reviewed the abstracts for highest quality. The venue was structured to facilitate interaction and discussions with farmers and other interested parties. As a result of invited presenters, the Organic Agriculture Soil Health Research Symposium brought together researchers, educators, extension personnel, industry leaders, farmers and ranchers to report on current research results in improving organic agriculture, identify research, education and extension needs, and advance the understanding of organic issues and problems using a systems-based approach related to soil health. The discussion was applicable to both organic and conventional production systems to improve sustainability and profit. The meeting attracted many researchers working in conventional systems who were looking for a better understanding of organic methods that could enhance conventional production systems. There were approximately 100 attends at the symposium, including researchers, farmers, students, and agricultural advisors. Scholarships were available to encourage the attendance of students and farmers to learn about and use the research results that was presented. Concurrent with the presentations was a live webinar and recording of the session by eOrganic. This recording has been maintained by eOrganic for future viewing. 120 attended the initial webinar and with continuing viewing of the site to date. A survey was distributed to attendees to determine knowledge gained from the presentation related to soil health. (See appendix for survey documents) OFRF issued a call for abstracts to support presenters for several other sessions throughout the conference. In addition to the symposium, several individual oral and poster presentations were done in six other sessions of the Tri-Societies meetings. (See proceedings in the appendix for presentation topics) A policy topic was presented by OFRF staff at the American Society of Agronomy's National and International Policy and Incentives for Soil Health Oral Session. The presentation discussed the need to increase public support for organic agricultural research in the 2018 Farm Bill. Other presentation sessions included the Soil Health for Agroecosystems Oral Session, General Organic Management Systems Oral I session, Soil Health for Agroecosystems Poster Session, General Organic Management Systems Oral II, and the Influence of Organic Manures on Growth and Yield of Soybean and on Soil Quality. Summary of these talks are in the Proceedings. Southern Sustainable Agriculture Working Group, February, 2018 workshop National Sustainable Agriculture Coalition conference, June, 2018 Approximately 100 attendees at the NSAC annual meeting were provided with crop insurance and soil health booklets developed by OFR based on current research results and support options available to organic farmers and ranchers. American Society of Horticultural Science, August, 2018, Washington, DC The ASHS oral presentation was on organic research results. The growing body of organic research that is available to researchers, extension, and farmers was discussed. The presentation provided information about current research topics and results that are adoptable for farmers and ranchers and furthering the next generation of research. Results on production practices, breeding, and economic trends from USDA-funded and OFRF-funded research from the past decade were highlighted. Special focus was on soil health and organic production. Participants learned who funds major organic research and where funds have been spent. An interactive discussion was held to gather input about future organic research needs. Carolina Farm Stewardship

Association, November, 2018, Durham, NC Putting Organic Research into Practice on Your Farm and Information Resources was the topic for this workshop. A power point presentation on Organic Production and Soil Health and accompanying presentation notes was provided to the forty attendees. After the presentation, discussion allowed those attending to ask more detailed questions specific to their farming operations and provide additional results from their production practices. The group was especially knowledgeable about organic agriculture and contributed to the information that was provided in the detailed presentation. The attendees appreciated the written handouts that accompanied the presentation. The power point and notes are provided in the Appendix. **\*\*PUBLICATIONS (not previously reported):\*\*** 2017/09 TO 2019/08 No publications reported this period.

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# Adapting and Expanding High Tunnel Organic Vegetable Production for the Southeast

<b>Accession No.</b>	1013077
<b>Project No.</b>	FLA-HOS-005634
<b>Agency</b>	NIFA FLA\
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26813
<b>Proposal No.</b>	2017-02475
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2021
<b>Grant Amount</b>	\$1,918,673
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Zhao, X.; Swisher, MA, E.; Bolques, AL, .; Hodges, AM, C.; Coolong, TI, .; Gao, ZH, .; Diaz-Perez, JU, CA.; Dufault, NI, S.; Legaspi, JE, CR.; O'Connell, SU, .
<b>Performing Institution</b>	UNIVERSITY OF FLORIDA, G022 MCCARTY HALL, GAINESVILLE, FLORIDA 32611

## NON-TECHNICAL SUMMARY

High tunnel production systems hold unique potential to address the challenges of organic vegetable production in the Southeast by providing an economical protected agriculture system that may help growers overcome many disease and pest problems and soil and water management issues that currently limit their chances of success, while promoting local food systems. This project builds upon a collaborative effort of the University of Florida, University of Georgia, Florida A&M University, and USDA-Agricultural Research Service. We address seven research and four outreach objectives in an integrated approach to address key needs for organic vegetable production in high tunnels. The long-term goal is to develop a strategic plan for research and extension in organic high tunnel vegetable production to address a more complete range of needs. We used interviews and surveys with organic vegetable growers using high tunnels to identify research needs and the key crops of interest. The biological research has four components: (1) environmental management for temperature and humidity, (2) crop management for season extension and multiple cropping, (3) soil and nutrient management, and (4) disease and pest management. The combined data will permit assessment of the interactions between these components of the high tunnel production system. Data from on-station and on-farm trials provide the basis for economic assessment of all biological research. We generate stakeholder involvement through an advisory panel of growers, non-profit organizations, Extension personnel, NRCS, and for-profit companies involved in high tunnel technology. Panel members assess the biological research, conduct on-farm trials, and participate in outreach activities. Extension activities include on-site field days, on-line educational materials that provide growers with the ability to observe field trials throughout the year, and traditional venues like workshops. We analyze additional data from surveys, on-farm trials, on-site field days, and users of on-line outreach materials to understand barriers to adoption of high tunnels and to the specific management practices that we examine. By building a strong partnership with organic producers and other stakeholders, this project will target long-term environmental and economic sustainability.

## OBJECTIVES

The long-term goal of the project is to develop sustainable high tunnel systems to promote the growth and expansion of organic vegetable production in the Southeast. This project will focus on the following research objectives: (1). Assess the efficacy of environmental control measures including shading, ventilation, and other cooling approaches on crop growth, yield, and quality of organically grown solanaceous vegetables and leafy greens under high tunnels; (2). Optimize planting time for high-tunnel produced tomatoes and leafy greens for early production and season extension and examine its impacts on nutrient availability and dynamics in organically managed high tunnel systems; (3). Determine the influence of integrated nutrient management practices on nutrient use efficiency and soil quality in high tunnel organic vegetable production; (4). Monitor and characterize plant pathogens infecting high priority organic high tunnel crops, and integrate biological products and cultural practices into organic vegetable disease management for high tunnels; (5). Monitor population of arthropod pests and beneficials in high tunnel organic vegetable cropping systems; (6). Develop cultural and biological alternatives for managing whiteflies and aphids; and (7). Analyze on-farm economic viability of high tunnel organic vegetable production and identify the factors influencing high tunnel adoption among organic growers.

## APPROACH

Our research process, outreach activities, and evaluation of project impacts depend on building a network of active partners and collaborators, starting with those who played a key role in determining the priorities for this project. Our systematic, integrated process for stakeholder involvement, assessment, and outreach is designed to achieve three objectives. First, we want to form and support an active, informed advisory panel of farmers, extension agents, representatives of farmer organizations, and companies involved in providing goods and services for high tunnel users. Second, we want this panel to play a critical decision-making body in both the research and outreach components of this project, including on-farm trials, evolution of research protocols, and mobilization of growers. Third, we want the panel to assist us in the formation of additional collaborative efforts to address the needs of organic high tunnel users. Our partners include non-profit organizations representing farmers (Florida Certified Organic Growers and Consumers, Inc. and Georgia Organics), county extension agents, farmers, NRCS, and the Florida Black Farmers Association. We will clearly define their role, establish responsibilities, ensure transparency, and empower the stakeholders represented on our advisory panel to make decisions affecting project implementation. The outreach plan, on-going stakeholder involvement in the project and beyond, and assessment of the research are highly integrated in this project and is based on establishing a diverse, authoritative advisory panel that plays a key role in setting project priorities, conducting on-farm research, and supporting outreach activities. On-farm research includes several on-farm trials each year where growers select specific components of the on-station research to test on their own farms. Dissemination of what we learn occurs through traditional venues (field days), workshops and conferences, but will incorporate on-line materials primarily in the form of short videos that allow producers to follow the developments in the field research throughout the growing season. The project outreach includes four key components: (1). An expanded network of farmers, farmer organizations and stakeholders that can share and access information about high tunnel organic vegetable production; (2). Continuing farmer and stakeholder participation in research and extension about high tunnel organic vegetable production; (3). Increased understanding of farmer and stakeholder decision making; and (4). Adoption of the management options generated by this research.

**\*\*Progress\*\*** 09/01/17 to 08/31/22 **\*\*Outputs\*\*** Target Audience: The primary target audience includes certified organic vegetable growers, transitional organic producers, growers who are interested in organic vegetable production, high tunnel growers, producers interested in using high tunnels for organic vegetable crops, beginning farmers and ranchers interested in organic production, scientists and researchers, educators, Extension personnel, agricultural service providers, agricultural consultants, and industry representatives. Project findings are also expected to be of interest to small- and medium-scale farmers, urban producers, minority and limited-resource growers, economically disadvantaged growers, undergraduate and graduate students in horticultural science, plant and soil sciences, entomology, plant pathology, and agricultural economics and other related programs, high school teachers and students interested in agricultural science, home gardeners, and backyard growers. Changes/Problems: While we were able to achieve the project objectives, we also encountered some problems and challenges that impacted the project implementation and outreach. Our project timeline had to be adjusted due to the delay in funding disbursement and project account establishment for all the PIs. High tunnel installation was not completed as initially scheduled because of the funding issue and other problems encountered during the construction process, causing a delay in starting the research trials. We also encountered some personnel change at the University of Georgia, as one of the co-PIs left the university. However, it did not cause any major impact on the project, as another co-PI at the University of Georgia was able to take the lead to complete the project activities. On Oct. 10, 2018, the high tunnel structure used for research and demonstration trials at the Florida A&M University Research and Extension Center (Quincy, FL) was destroyed due to Hurricane Michael, a category three storm that caused considerable damage to the area. Hurricane-force winds

that entered through the top vent roofing component of the structure were strong enough to lift the roof assembly and damage the end walls. The high tunnel structure was rebuilt in Apr. 2019. The COVID-19 pandemic presented challenges to completing planned research activities during 2020 and 2021. For example, restrictions that were implemented due to COVID-19 resulted in delays and complications in crop management, harvest, and laboratory work as well as data collection during the research trials. In some cases, we were unable to access the research trial in a timely manner to examine the crops and conduct experimental measurements. Disease, pest, and nutrient management was also negatively affected when travel to the research site became restricted and limited farming assistance to on-station trials was available. Due to the COVID-19 pandemic and maximized telework mandated by USDA, our USDA-ARS researcher on the project team was unable to complete field studies as originally planned. Because of the impact of COVID-19, the grower survey response rate was much lower than expected. Nevertheless, we collected responses from 45 growers and obtained valuable information on their attitude toward high tunnel adoption. We plan to continue collecting more data beyond the project period to enrich the grower survey data set in order to obtain more representative samples. Due to the pandemic, we also had to postpone the Extension agent survey, which will be completed in 2023. Our Extension and outreach programs and activities were significantly impacted by COVID-19. We had to cancel several in-person field days, workshops, and research assessment events. The no-cost extension allowed us to provide in-service training and organize project workshops in a face-to-face format in 2022. We conducted the third and fourth advisory panel meetings virtually via Zoom. The third research assessment was conducted in a hybrid format where participants completed their field observations in person and participated in a facilitated discussion via Zoom. We conducted the fourth and fifth research assessments in a virtual format where participants completed their observations using photos, entered their responses in an online instrument, and then participated in a facilitated discussion via Zoom. We will produce two additional virtual field day videos to replace field days we were unable to host due to COVID-19 restrictions. Conducting on-farm trials also became a major challenge because of the pandemic. We revised our on-farm trial protocol to accommodate contactless data collection and reduce the number of researchers in the farmers' fields. The on-farm high tunnel trials that focused on disease and pest monitoring turned out to be quite successful, and every participant commented that they benefitted from this outreach effort and would participate in a future on-farm trial. What opportunities for training and professional development has the project provided? Our project provided diverse opportunities for training and professional development. The high tunnel organic vegetable production research and demonstration sites established at the University of Florida Plant Science Research and Education Unit (Citra, FL), Florida A&M University Research and Extension Center (Quincy, FL), and the University of Georgia Horticulture Research Farms (Watkinsville and Tifton, GA) played a key role in facilitating project dissemination by allowing the researchers to offer a variety of on-site training events throughout the project period. The researchers, Extension experts, and educators on this project team have been actively involved in creating and developing various training and professional development programs. In addition to conducting regular grower-level training sessions and providing in-service training to Extension agents, we also organized research farm tours for high school students and growers in the new and beginning farmers and ranchers program to provide basic training in protected agriculture, high tunnel systems, vegetable production, organic farming, and field research setup. Five educational workshops have been held to discuss a wide range of topics related to season extension, high tunnel structures and environmental control, organic vegetable production and management in high tunnels, and economic analysis. We also engaged several Extension agents in moderating workshop sessions and providing hands-on demonstrations at the high tunnel workshops to help further enhance their practical skills. A Zoom video conference call with Extension faculty at Purdue University was conducted to discuss organic crop production research in high tunnels. In addition, we hosted a professor from the University of Puerto Rico-Utuado for her sabbatical visit to develop collaborative research and Extension projects on pest management in vegetable production under high tunnels. Through this partnership, we delivered a presentation at the online high tunnel workshop to specialty crop growers in Puerto Rico. We incorporated research findings from this project into teaching modules of undergraduate courses on organic and sustainable crop production at the University of Florida. We recruited several undergraduate students to participate in project research activities, which helped cultivate their interest in organic agriculture research and develop their basic skills for performing field and laboratory work. We also hosted an undergraduate summer research intern at the University of Florida to engage the student in carrying out an independent study as part of the high tunnel organic tomato production trial. Interdisciplinary training opportunities have been offered to many graduate students who are active members of this project, including three Doctor of Plant Medicine (DPM) students, one M.S. student and two Ph.D. students in horticultural science, one M.S. student and three Ph.D. students in food and resource economics, and one Ph.D. student in interdisciplinary ecology. We guided them in leading and conducting various research activities such as designing and implementing research experiments, disease and pest monitoring, identification, and management, soil and plant sampling, fruit quality assessment, data collection and statistical analysis, cost and return analysis, designing and conducting surveys, writing reports and manuscripts, and presenting research findings. Their research activities are interconnected through field trials and teamwork that serve multiple objectives across

different disciplines. The graduate students presented their research progress during our monthly project meetings and also actively participated in a series of project Extension and outreach events and activities. One of the graduate students played a major role in organizing field research trial assessment and advisory panel meetings. The graduate researchers have presented project results at local, regional, national, and international scientific conferences, and they authored or co-authored research and Extension publications. This project has provided a unique opportunity for graduate students to interact with growers and Extension agents and develop multifaceted professional skills in a transdisciplinary context. How have the results been disseminated to communities of interest? The outreach program was focused on the following components: (1) An expanded network of farmers, farmer organizations and stakeholders that can share and access information about high tunnel organic vegetable production; (2) continuing farmer and stakeholder participation in research and Extension about high tunnel organic vegetable production; (3) increased understanding of farmer and stakeholder decision making; and (4) adoption of the management options generated by this research. We have widely disseminated project results through the Cooperative Extension Service at the University of Florida, Florida A&M University, and the University of Georgia. Local and regional educational programs including field days, training sessions, and workshops have been conducted featuring the research conducted in this project. In Florida, we engaged Extension agents in outreach programming. In Georgia, a co-PI on the project team met with Extension agents from all districts to discuss the ongoing research related to this project so that the clientele most interested in this research could be reached by local educational programming. We were also invited to some grower meetings and outreach events in other states where project information was discussed. In addition to Extension and outreach talks, we have presented project information on different topics through Extension publications and newsletter articles that are accessible online. A website was also created for project dissemination, and we have updated it throughout the project. We are finalizing our virtual field day videos and topical videos showcasing the research. Two videos have been completed and posted to YouTube, and we will produce four virtual field day videos and eight project videos by summer of 2023. Research findings have been communicated with the scientific community through a number of presentations at local, regional, national, and international conferences during 2018-2022. Some of the project results have been published in refereed journals, and more are in the pipeline. The advisory panel also played an essential role in project implementation and dissemination. We recruited five members for the project advisory panel (two organic producers and three agricultural service providers) and held the first advisory panel meeting on Mar. 28, 2019 in Gainesville, FL. We recruited three additional members for the advisory panel (two organic producers and one agricultural service provider) and held the second advisory panel meeting on Mar. 3, 2020, in Tifton, GA. In 2021, we recruited five additional members for the advisory panel (three Extension agents and two agricultural service providers) and held the third advisory panel meeting virtually via Zoom on Mar. 3. We held our fourth and final advisory panel meeting virtually via Zoom on Mar. 14, 2022. Project research objectives and activities were presented to the advisory panel for their feedback on research design, project outreach, and stakeholder engagement. In addition, we asked the advisory panel to assess our project progress and provide recommendations for research implementation. The advisory panel meeting report and research presentation slides were distributed to the research team and advisory panel members. We have collaborated with Florida Certified Organic Growers and Consumers, Inc. and Georgia Organics to seek their input. Project dissemination was also conducted through field research assessment. We conducted our research assessment in Citra, FL at the University of Florida Plant Science Research and Education Unit on Apr. 25, 2019 (ten participants), Nov. 5, 2019 (six participants), and Mar. 16, 2021 (nine participants). We recruited eight participants and conducted the fourth research assessment on Apr. 22, 2021 virtually via Zoom. The final research assessment was conducted on Aug. 25, 2022 (four participants) virtually via Zoom. The research assessment provided a great opportunity for farmers and agricultural service providers to evaluate the experimental treatments tested in field research trials and identify potential benefits and limitations of our research. The research assessment reports were distributed to the research team and participants and were posted on the project webpage. In addition, we recruited five farmers to conduct five on-farm trials in Florida from Oct. 2021 through June 2022. Participants collected weekly pest data through passive trapping using sticky cards. Participants also scouted and collected disease data through collection of plant tissues (fruit, foliage, or roots) as needed. Weekly pest counts were conducted, and results were sent to participants on a weekly basis. We conducted follow-up interviews to get feedback from participants about the benefits and challenges of participating in the on-farm trials. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported \*\*Impacts\*\* What was accomplished under these goals? Research objectives 1, 2, and 3 on environmental control, planting dates, and integrated nutrient management: The 2-year high tunnel organic basil, lettuce, and arugula trials (Watkinsville, GA) with transplanting dates in mid-Sept. and early Oct. showed that earlier planting increased lettuce and basil yields but reduced the yield of arugula. Shade cloth (30%) and fogging systems did not impact crop yields. Shaded high tunnels showed lower air and soil temperatures than non-shaded tunnels, while fogging systems increased canopy leaf wetness. Planting date and shading exhibited greater impacts on leaf nutrient contents than fogging. The 2-year high tunnel organic tomato trials (Tifton, GA) evaluating shade net (black, silver, and no shade control) and plastic

mulch (black and white) treatments demonstrated that both black and silver nets improved plant growth during the summer due to reducing temperatures inside the tunnel. However, shade nets reduced fruit yield in contrast to the uncovered tunnel because of decreased light in tunnels with nets during the tomato fruiting stage. While plant growth was enhanced by white vs. black mulch, plastic mulch color did not affect tomato yield components. The multi-season high tunnel organic leaf lettuce trials conducted in Quincy, FL compared 15 cultivars for yield performance and heat and bolting tolerance. Plant health was improved by the high tunnel environment compared to open field production. Top performing lettuce cultivars were identified in high tunnel and open field systems. The high tunnel organic grape tomato trials (Citra, FL) showed greater fruit yields with early planting (late Jan.) than late planting (early Mar.), and yield improvement by using vigorous rootstocks was also compromised by late planting. Although fruit nutrient contents based on dry weight were increased by rootstocks for both plantings, grafted tomato fruit sensory quality tended to decrease with late planting. Another 3-year (2018-2021) high tunnel organic vegetable cropping system study (Citra, FL) was completed to examine the influence of integrated nutrient management practices on plant growth, crop yield and quality, nitrogen availability and use efficiency, and soil health under Florida sandy soil conditions. Cowpea cover crop (with fallow control) was planted each summer, followed by pac choi (fall), lettuce/spinach (winter), and tomato (spring). Compost (cow manure-based compost, yard waste-based compost, vermicompost, and no compost control) and organic fertilizer (granular vs. liquid) treatments were applied in pac choi and tomato production. Cowpea cover crop showed limited effects on improving vegetable yields and soil health. Using liquid organic fertilizer and compost helped improve nitrogen use efficiency and vegetable yields. Compost and granular organic fertilizer application exhibited positive impacts on long-term soil health enhancement. Research objectives 4, 5, and 6 on disease and pest management: In the 3-year high tunnel study in Citra, FL, powdery mildew (*Pseudoidium neolycopersici*) was detected in 2019, while tomato leaf mold (*Passalora fulva*) was identified as the major disease in 2020 and 2021. Other diseases with very low incidences included *Sclerotinia* stem rot (*Sclerotinia* spp.) and gray mold (*Botrytis cinerea*). The dominant pathogen was found to be highly dependent on seasonal conditions and management techniques. Using a tomato yellow leaf curl virus (TYLCV) resistant cultivar and grafting with the disease-resistant rootstock demonstrated their effectiveness for tomato disease management. Although TYLCV was not observed, tomato chlorosis virus (TCV) and tomato spotted wilt virus (TSWV) were detected. High tunnel crop producers will need to be vigilant of other opportunistic and novel diseases that can impact crop yields while they focus on controlling the major diseases encountered. The survey of plant diseases in high tunnels was also completed at five commercial farms in Florida. Early blight (*Alternaria* spp.) and Fusarium wilt (*Fusarium oxysporum* f. sp. *lycopersici*) were the major diseases identified, which differed from those observed in the on-station trials. Our findings provide a knowledge change in that it has made researchers and stakeholders more aware of the variation we see in diseases related to high tunnel production. Multiple biological products for disease management were used in the on-station trials along with cultural practices; however, the variability in disease presence did not lead to any conclusive results. Selection of resistant cultivars including grafted plants and incorporation of non-host rotational crops will be critical to organic tomato high tunnel disease management, and biological fungicides may be incorporated with accurate disease diagnoses. The most captured pests on sticky cards were whiteflies and thrips during the on-station trials in Citra. Aphids, leaf miners, and planthoppers were also detected, but their numbers were significantly lower than whiteflies or thrips. Visual inspections of plants revealed the presence of various stink bug species. All life stages were observed both on foliage and fruit with some fruit showing feeding damage as they matured. Other minor pests included armyworms, tobacco hornworms, and garden fleahoppers. The most common beneficial insects found on the sticky cards were parasitoid wasps (Hymenoptera: Apocrita); notable families included Aphelinidae, Braconidae, Mymaridae, and Scelionidae. Parasitoid wasps were consistently collected throughout each season with larger numbers found toward the beginning and the end of the season. High tunnel trials in Quincy, FL and Tifton, GA identified sweetpotato whiteflies, aphids, and thrips as the major insect pests and showed the potential of companion planting of flowering plants and cover crops (e.g., marigold, sweet alyssum, buckwheat) to attract beneficial insects (e.g., big-eyed bugs, ladybeetles, lacewings, whitefly parasites *Encarsia* spp. and *Eretmocerus* spp.) and enhance biological control in high tunnel organic vegetable production. The "push-pull" technology evaluation in a high tunnel organic tomato trial (Quincy, FL) included citronella, garlic chives, and lemon grass as the "push" component and green leaf volatiles (GLV) as the "pull" component. Marigold and basil plants and commercial "predalure" volatiles were used to complement the push-pull strategy by enhancing the beneficial insect population. Results suggested that the push-pull technology complemented with the use of flowering plants and commercial attractants of beneficial insects may be part of an IPM program to control major insect pests in high tunnel organic vegetable production. Repellent plants and attractive flowering plants together with commercial "predalure" were further assessed in another high tunnel organic leafy green trial. Different GLVs were also tested as attractants of sweetpotato whiteflies and cis-3-hexenyl acetate was shown to be attractive. Research objective 7 on economic analysis and high tunnel adoption: Based on the on-station trials, we developed budget sheets for estimating high tunnel construction costs and analyzing the costs and benefits of high tunnel organic vegetable production. Sensitivity analysis and breakeven analysis were also carried out to estimate the impact of

different factors (e.g., transplant price and tomato price) on the net return of grafted and non-grafted tomato production using high tunnels. A grower survey was conducted in FL and GA to understand growers' perceptions and attitudes toward using high tunnels in organic crop production. While many organic growers recognize the benefits of high tunnels for improving organic vegetable production, there is a critical need for developing Extension and outreach programs to provide more technical support regarding soil and nutrient management, disease and pest control, and crop and cultivar selection. \*\*Publications\*\* - Type: Journal Articles Status: Published Year Published: 2022 Citation: Nian, Y., R. Zhao, S. Tian, X. Zhao, and Z. Gao. 2022. Economic analysis of grafted organic tomato production in high tunnels. *HortTechnology* 32:459-470. - Type: Journal Articles Status: Published Year Published: 2022 Citation: Gong, T., X. Zhang, J.K. Brecht, T. Serrano, C. Sims, J. Colee, and X. 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UF/IFAS Extension EDIS publication (In preparation). - Type: Websites Status: Published Year Published: 2019 Citation: Project website: <https://floridafoodandag.com/new-home/adapting-and-expanding-high-tunnel-vegetable-crop-production> \*\*Progress\*\* 09/01/20 to 08/31/21 \*\*Outputs\*\* Target Audience: The target audience includes certified organic vegetable growers, transitional organic producers, growers who are interested in organic vegetable production, high tunnel growers, producers interested in using high tunnels for organic vegetable crops, minority and limited-resource growers, beginning farmers and ranchers interested in organic production, small farm and urban farm producers, scientists and researchers, educators, extension personnel, agricultural service providers, agricultural consultants, industry representatives, undergraduate and graduate students, high school students interested in agricultural science, home gardeners, backyard growers, and the general public. Changes/Problems: The COVID-19 pandemic continued to present challenges to completing planned research and outreach activities during this reporting period. Some field research experiments and in-person outreach activities had to be cancelled and the grower survey had to be postponed. We augmented our planned activities to comply with research restrictions by reworking the activity to a hybrid or virtual format. We conducted the third advisory panel meeting virtually via Zoom. We conducted the third research assessment in a hybrid format where participants completed their field observations in person and participated in a facilitated discussion via Zoom. We conducted the fourth research assessment in a virtual format where participants completed their observations using photos and entering their responses in an online instrument and participated in a facilitated discussion via Zoom. We will produce two additional virtual field day videos to replace field days we were unable to host due to COVID-19 restrictions. We were unable to conduct on-farm trials to date due to both COVID-19 restrictions and not wanting to burden farmers with conducting research during such a stressful time. We will now complete our on-farm trials focusing on pest and disease incidence and management from Nov. 2021 through May 2022 at five farms throughout Florida. What opportunities for training and professional development has the project provided? During this reporting period, our project continued to provide diverse opportunities for training and professional development. At the Florida A&M University Research and Extension Center, research farm tours were offered to beginning farmers. Attendees learned about up-to-date research information on leaf lettuce production in a high tunnel, organic production, barriers to organic leaf lettuce production, plant bolting concerns, and key

components of an in-ground experimental plot design. Through the partnership with our collaborator at the University of Puerto Rico-Utuado, we presented at the online high tunnel workshop to specialty crop growers in Puerto Rico. We also discussed our research findings at two other workshops on sustainable vegetable production and protected agriculture organized by University of Florida researchers and extension agents. In addition, we conducted a virtual high tunnel tomato cultivar assessment that involved a diverse group of organic farmers and vegetable growers. We also continued to incorporate research findings from this project into teaching modules of undergraduate courses on organic and sustainable crop production at the University of Florida. We recruited a number of undergraduate students to participate in project research activities to gain a basic understanding of organic vegetable production in high tunnels and develop multifaceted skills in field and laboratory research. Interdisciplinary training opportunities have been offered to graduate students in different programs such as horticultural sciences, plant pathology, entomology, food and resource economics, and interdisciplinary ecology. Their research activities are interconnected through field trials and teamwork that serve multiple objectives across different disciplines. The graduate students have been presenting their research progress during our monthly project meetings and they are also actively involved in project outreach programs. One of the graduate students has been playing a major role in leading the effort of organizing grower assessment of research trials and advisory panel meetings. How have the results been disseminated to communities of interest? During this reporting period, we presented project information at various conferences and stakeholder meetings such as the American Society for Horticultural Science Annual Conference and the Southeast Regional Fruit & Vegetable Conference. Research findings were also disseminated through presentations at various workshops, research farm tours, local county level meetings with extension agents and growers, newsletters, and the project webpage. Research and extension publications have been produced. We updated the project webpage throughout the year and continued to take photos of field research for the webpage and the development of the virtual field day videos and topical videos showcasing the research activities. Up-to-date project results were also presented at our annual advisory panel meeting. We recruited five additional members for the advisory panel (three Extension agents and two agricultural service providers) and held the third advisory panel meeting virtually via Zoom on 3 Mar. 2021. Nine participants were recruited to help conduct our third research assessment on 16 Mar. 2021 at PSREU in Citra, FL. We also recruited eight participants and conducted our fourth research assessment on 22 Apr. 2021 virtually via Zoom. The third advisory panel meeting report was distributed to the research team and advisory panel members. The third and fourth research assessment reports were distributed to the research team and stakeholder participants. All the reports are posted on our project webpage. What do you plan to do during the next reporting period to accomplish the goals? We plan to complete this project during the next reporting period. The high tunnel lettuce cultivar evaluation trials will be continued at the Florida A&M University research site in Quincy, FL. We will demonstrate the "push-pull" strategy complemented with the use of a commercial mix of beneficial flowering plants, to control insect pests in organic vegetables in high tunnels. All the remaining research samples will be processed, and data analysis and synthesis will be performed for all the research trials conducted at different sites in Florida and Georgia. We will obtain more data on the research trials and continue the economic cost and benefit analysis. The high tunnel survey instrument will be finalized and distributed to growers in Georgia and Florida for identifying the factors that influence high tunnel adoption among farmers. Research manuscripts will be submitted for publication in peer-reviewed journals and extension publications on various aspects of high tunnel organic vegetable production systems will be prepared. We plan to present project findings at professional conferences and grower meetings and disseminate research results to organic producers through a variety of extension activities such as the 2022 High Tunnel Workshops and Alternative Crop Enterprise programs. We will host the final advisory panel meeting virtually via Zoom. We also plan to host a virtual tomato cultivar assessment using the data and photos from the 2020 high tunnel organic tomato trial in Watkinsville, GA. We will produce four virtual field day videos showcasing four treatments from the high tunnel organic tomato trials conducted in Citra, FL. We will produce one virtual field day video showcasing the 2020 high tunnel organic tomato cultivar trial in Watkinsville, GA. We also plan to produce eight topical videos showcasing some of the project findings. Additionally, we will complete on-farm trials monitoring pest and disease incidence and management from Nov. 2021 through May 2022 at five farms in Florida. **\*\*Impacts\*\*** What was accomplished under these goals? Research objectives 1, 2, and 3: Assess the efficacy of environmental control measures on organic vegetable production under high tunnels; Optimize planting time for high-tunnel produced organic vegetables; Determine the influence of integrated nutrient management practices on nutrient use efficiency and soil quality in high tunnel organic vegetable production. At the University of Georgia research site in Tifton, research trials were continued to determine the influence of shade and plastic mulch treatments on crop growth, yield, and quality, and environmental conditions of tomato and lettuce grown in organically managed high tunnels. Different planting dates were also examined for high tunnel tomato production toward optimizing crop productivity and season extension. The graduate student leading the work on assessing the effects of shade cloth in combination with over-head misting on growth of organic spinach and arugula under high tunnels at the University of Georgia research site in Watkinsville received her M.S. degree in Aug. 2020. She has taken a position in Cooperative Extension as a County Agent in North

Carolina. At the Florida A&M University research site in Quincy, the research work was focused on comparing the production of different leafy greens in a top vented structure in North Florida. Growth, yield, and quality of organically grown leaf lettuce in a tropical screen house high tunnel and the open field were evaluated during this reporting period. Four evaluation cycles were achieved, including 17 Nov. to 24 Dec. 2020, 5 Mar. to 25 May 2021, 5 May to 5 July 2021, and 23 June to 25 Aug. 2021. Eleven lettuce cultivars were evaluated with three replications in a randomized complete block design. Lettuce seedlings were planted in the high tunnel and open field 37 days after seeding in the greenhouse. Data collection began three weeks after planting in the high tunnel and open field. Assessment of plant performance parameters showed that the greatest percentage of heads ranked in the average category was 60.8% in the open field and 57.3% in the high tunnel. Plant vigor ratings were also greatest in the moderate category, with 59.7% in the open field and 54.5% in the high tunnel. Healthier plants were observed in the high tunnel, where 86.3% were in the very healthy category. Conversely, only 51.6% of the plants in the open field were in the very healthy category. Early bolting cultivars included loose leaf lettuce 'Vulcan' in the open field and 'Green Star', 'Star Fighter', and 'Vulcan'; in the high tunnel. Late bolting cultivars included summer crisp lettuce 'Nevada' and 'Magenta' and oakleaf lettuce 'Panisse' in both production systems. By the end of this reporting period, we have completed the three-year study at the University of Florida Plant Science Research and Education Unit (PSREU) in Citra with an emphasis on evaluating integrated nutrient management practices for high tunnel organic vegetable production. Findings from the third year study demonstrated that the cowpea cover crop had little influence on improving the yield of leafy greens and tomato. In the leafy green season, weekly liquid fertilization led to a significantly higher yield of pac choi than the application of preplant granular fertilizer, while the yard waste based-compost treatment tended to enhance the total yield of pac choi and the subsequent baby lettuce crop compared with the no compost control. For the tomato season, weekly application of the liquid organic fertilizer resulted in significantly higher total and marketable yield and fruit numbers in contrast to using the granular organic fertilizer at preplant and through sidedressing. Grafted tomato plants produced significantly higher fruit number and yield compared with the non-grafted plants. The soil samples were collected at the end of tomato season to assess soil health indicators. No significant differences were found between the cowpea cover crop treatment and the weedy fallow control. Granular fertilization exhibited the potential for improving the overall fertility score in comparison with the liquid fertilizer treatment. The yard waste based-compost and cow manure-based compost treatments helped increase soil organic matter content and enhance aggregate stability and soil health and overall fertility scores while reducing dry soil bulk density. Vegetable samples for quality assessment are also being analyzed with data processing ongoing.

Research objectives 4 and 5: Monitor and characterize plant pathogens infecting high priority organic high tunnel crops; Monitor population of arthropod pests and beneficials in high tunnel organic vegetable cropping systems. During this reporting period, we continued to monitor plant diseases during the high tunnel organic vegetable production trials conducted at PSREU in Citra, FL. An extension publication is being prepared with respect to identifying major tomato disease problems in organic high tunnel systems. Pest and beneficial insect monitoring data were also collected for the high tunnel experiments at PSREU, on at least 30 data collection points during the reporting period. Over 10,000 specimens were identified from yellow sticky cards and through visual observation. A data synthesis table was constructed to highlight the taxa summary of pest and beneficial insects identified in the organically managed high tunnel during the reporting period. Objective 6: Develop cultural and biological alternatives for managing whiteflies and aphids. We continued to process the data from previous seasons collected in high tunnels in Quincy, FL and Tifton, GA. Preliminary results from yellow stick trap samples collected in a tomato crop in a high tunnel at the University of Georgia in Tifton, GA from Mar. to Apr. 2019 showed that the major and most abundant insect pest was thrips followed by aphids and sweetpotato whitefly. A few whitefly parasites, *Encarsia* spp. and *Eretmocerus* spp. were collected. Objective 7: Analyze on-farm economic viability of high tunnel organic vegetable production and identify the factors influencing high tunnel adoption among organic growers. We developed R coding to conduct the cost and benefit analysis of organic vegetable production under high tunnels using the on-station research trial data from the past two years (2018-2019 and 2019-2020) with respect to organic tomato, pac choi, and spinach. We estimated the annual total cost and net return for growing organic vegetables under high tunnels. Sensitivity analysis was also performed to determine the effect of grafted transplant price and tomato market price on the economic return of tomato (grafted vs. non-grafted) production in organically managed high tunnels. In addition, we developed a draft of the high tunnel grower survey aimed at determining organic growers' perception and attitude toward high tunnel adoption for vegetable production. \*\*Publications\*\* - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Bag, S., J. Bautista, G. Gunawan, M. Bashyal, T.W. Coolong, H. Milner, and J.C. Diaz-Perez. 2021. Organic tomato grown in high tunnels as affected by shade net and plastic mulch color. American Society for Horticultural Science Annual Conference, Denver, CO. (virtual presentation) - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Donovan, M., M.E. Swisher, K. Sattanno, and X. Zhao. 2021. Grower assessment of organic tomato nutrient management factors in a high tunnel. American Society for Horticultural Science Annual Conference, Denver, CO. (virtual presentation) - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Tian, S., X. Zhao,

and J. Brecht. 2021. Assessing grafting and integrated nutrient management practices, including cover crop, composts, and organic fertilizers, on organic high tunnel tomato production. American Society for Horticultural Science Annual Conference, Denver, CO. (virtual presentation) - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Zhao, R., Y. Nian, Z. Gao, X. Zhao, and S. Tian. 2021. Cost and benefit analysis of grafted tomato production in organically managed high tunnels. American Society for Horticultural Science Annual Conference, Denver, CO. (virtual presentation) - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Zhao, X. 2021. Soil and nutrient management for high tunnel organic vegetable production: Case studies in Florida. Southeast Regional Fruit & Vegetable Conference, Savannah, GA. (virtual presentation) - Type: Journal Articles Status: Published Year Published: 2021 Citation: Laur, S., A.L.B.R. da Silva, J.C. D az-P rez, and T. Coolong. 2021. Impact of shade and fogging on high tunnel production and mineral content of organically grown lettuce, basil, and arugula in Georgia. Agriculture 11:625. - Type: Other Status: Published Year Published: 2021 Citation: Laur, S., M. Donavan, J.C. D az-P rez, and T. Coolong. 2021. Extending the growing season for lettuce in Georgia using shade cloth and high tunnels. University of Georgia Extension Circular 1241. - Type: Other Status: Other Year Published: 2021 Citation: Zhao, X. 2021. Integrated practices for improving organic vegetable production. Sustainable Vegetable Production Workshop, Citra, FL. - Type: Other Status: Other Year Published: 2021 Citation: Zhao, X. 2021. Organic tomato production in high tunnels. Virtual Workshop on Vegetable Production in Greenhouses & High Tunnels (FL). - Type: Other Status: Other Year Published: 2021 Citation: Zhao, X. 2021. High tunnel systems for improving organic vegetable production. Virtual Workshop on High Tunnel Production Systems (PR).

## PROGRESS

2018/09 TO 2019/08 Target Audience: The target audience includes certified organic vegetable growers, transitional organic producers, growers who are interested in organic vegetable production, high tunnel growers, producers interested in using high tunnels for organic vegetable crops, minority and limited-resource growers, small farm and urban farm producers, researchers and educators, extension personnel, service providers, agricultural consultants, industry representatives, undergraduate and graduate students, and the general public. Changes/Problems: Due to Hurricane Michael in Oct. 2018, the screenhouse used for research trials at the Florida A&M University Research and Extension Center (Quincy) was destroyed and thus, the fall 2018 season planting of leafy green vegetables had to be postponed. The new structure was completed at no cost by the manufacturer in spring 2019 and the site is ready for the fall 2019 trial. In Tifton, GA, tomato yellow leaf curl virus negatively affected tomato yields for the fall-winter planted tomato trial. Another challenge we encountered was associated with on-farm trials. In 2018, shade cloth was purchased for on-farm trials for the production of mid-summer crops (ginger and turmeric) at the participating farm in Alamo, GA. However, under excessive rain and cloudy weather conditions, the grower did not wish to use the shade cloth. Instead, a new trial was discussed and designed using low tunnels for the production of strawberries on plastic mulch, which will begin in winter 2019. Based on grower discussion in the Athens, GA region, we are planning different approaches for upcoming on-farm trials that will feature different techniques to improve organic high tunnel production in Georgia. What opportunities for training and professional development has the project provided? We have provided 2 grower training workshops (county-level) on high tunnel crop production in Rabun and Habersham counties in GA. We are also scheduled to participate in 2 workshops in the Athens region in GA featuring off-season production of lettuce in organic high tunnels on 12 and 25 Sept. 2019. An educational talk on conservation biological control was delivered during the 2019 Vineyard Management, IPM and Pesticide Safety Workshop held at the Center for Viticulture and Small Fruit Research, Florida A&M University, Tallahassee, FL on 13 Feb. 2019. We continued to offer training opportunities to graduate students involved in the project by guiding them to lead and conduct various research activities such as designing and implementing research experiments, disease and pest monitoring, identification, and management, soil and plant sampling, data collection and statistical analysis, fruit quality assessment, developing enterprise budget for economics analysis, report preparation, and research presentation. Furthermore, the graduate students as active participants in the project have been developing interdisciplinary collaboration skills by working with project team members from different fields. We also engaged several undergraduate research assistants in the project to help cultivate their interest in organic agriculture research and develop their basic skills in field and laboratory work settings. In addition, research findings from the project have been well integrated into course teaching materials on organic and sustainable crop production at the University of Florida. How have the results been disseminated to communities of interest? We recruited five members for the advisory panel (two organic producers and three agricultural service providers) and held the first advisory panel meeting on 28 Mar. 2019 in Gainesville, FL. Project research objectives and activities conducted to date for each objective were presented to the advisory panel for their feedback on research design, project outreach, on-farm trials, and stakeholder engagement. In addition, we asked the advisory panel to help assess our project progress and provide recommendations for research implementation. The advisory panel meeting report and research presentation slides were distributed to the research team and advisory panel members. We

also recruited 10 participants and conducted our first research assessment of the high tunnel organic tomato study on 25 Apr. 2019 at PSREU in Citra, FL. This research assessment provided a great opportunity for farmers and agricultural service providers to evaluate the experimental treatments tested on-site and identify potential benefits and limitations of our research toward future study improvement. The research assessment report was distributed to the research team and the participants. Reports from our first advisory panel meeting and research assessment have been posted on the project webpage. We updated the project webpage throughout the year and continued to take photos of research trials for the website and the development of the virtual field day and videos. The project information has been disseminated through workshops and field days organized by the project team members and research findings have been presented at professional conferences. Project dissemination also took place at Tallahassee Science Festival, Tallahassee, FL (3 Nov. 2018), Vineyard Management, IPM, and Pesticide Safety Workshop, Florida A&M University Center for Viticulture and Small Fruit Research, Tallahassee, FL (13 Feb. 2019), AGRI-STEM Camp for middle school students, Florida A&M University, USDA-ARS-CMAVE, Tallahassee, FL (31 July 2019), and Grape Harvest Festival, Florida A&M University Center for Viticulture and Small Fruit Research, Tallahassee, FL (24 Aug. 2019). What do you plan to do during the next reporting period to accomplish the goals? During the next reporting period, we will continue to conduct the high tunnel organic vegetable cropping system experiments and collect research data at different locations in Florida and Georgia for each research objective. We also expect to identify grower collaborators to begin on-farm trials. The high tunnel budget sheet will be further developed with sensitivity and break-even analysis included. A survey instrument will be designed with the objective of identifying key factors that influence high tunnel adoption among farmers. We will continue our monthly project meetings to facilitate project coordination and implementation. We plan to recruit five additional members for the advisory panel and host our second advisory panel meeting in Georgia. We will conduct research assessments in both Florida and Georgia and organize workshops and field days for project dissemination. We will continue to take photos of the biological research for our webpage and those photos will be used to develop topical videos showcasing this project. We will create and launch our online virtual field day assessment. We will continue to present research results at professional conferences and meetings with growers and extension agents, and we will begin to disseminate project findings via peer-reviewed journal articles and extension publications.

2019/09 TO 2020/08 Target Audience: The target audience includes high tunnel growers, certified organic vegetable growers, producers interested in using high tunnels for organic vegetable crops, growers who are interested in organic crop production, minority and limited-resource growers, small-scale farming operations, urban farm producers, beginning farmers, researchers and educators, extension personnel, agricultural consultants, industry representatives, undergraduate and graduate students in horticultural science, plant and soil sciences, entomology, plant pathology, and agricultural economics and other related programs, high school teachers and students interested in protected production of vegetables in the agricultural science education program, and the general public. Changes/Problems: Research restrictions that were implemented due to the COVID-19 pandemic presented a major challenge to the biological research beginning in Mar. 2020 and disrupted our planned outreach activities. Delays and complications in crop management, harvest, and laboratory work as well as data collection have been encountered during the research trials. In some cases, we were unable access the research trial to examine the crops and conduct experimental measurements. Disease and pest problems also turned out to be rather severe as a result of a lack of control measure implementation when travel to the research site became restricted and limited farming assistance to on-station trials was available. The difficulty in conducting field research also presented challenges to completing the estimated budget of high tunnel production using the data obtained from on-station field trials. Due to the COVID-19 pandemic and maximized telework mandated in USDA, our USDA-ARS researcher on the project team was unable to complete spring and summer 2020 field evaluations. At the Tifton, GA research site, we continued to see a high incidence of tomato yellow leaf curl virus in the high tunnel organic tomato trial although resistant cultivars have been used. Identification of tomato cultivars resistant to tomato yellow leaf curl virus for high tunnel production will be a focus of future studies. Due to the COVID-19 pandemic, we had to put the in-person survey of high tunnel producers on hold. A field day planned for June 2020 in Georgia had to be cancelled, and 2 workshops originally scheduled for Mar. and May 2020 in Florida were also cancelled. We were unable to host an in-person research assessment and field day scheduled for Apr. in Citra, FL due to the shutdown. Given the challenges associated with crop management, we also failed to produce a virtual assessment for the high tunnel tomato trial. The project team is delaying the on-farm trials till at least 2021 to be mindful of the pressure farmers are experiencing due to COVID-19. This will delay our outreach activities associated with the on-farm trials. What opportunities for training and professional development has the project provided? During this reporting period, our project provided a variety of opportunities for training and professional development. Two grower-level training sessions were conducted in north Georgia in 2020. At the Florida A&M University Research and Extension Center, research farm tours were offered to high school students and growers in the new and beginning farmers and ranchers program. Students learned about leaf lettuce and other leafy greens under organic production and in protected culture systems,

organic crop challenges, plant bolting concerns, and components of an in-ground experimental plot design. Trainees in the new and beginning farmers and ranchers program visited the protected agricultural areas at the Center, including the tropical screenhouse structure used in this project to obtain a comprehensive understanding of organic leaf lettuce production practices and possible solutions to address off-season production constraints. A Zoom video conference call with extension faculty at Purdue University was conducted to discuss organic crop production research in high tunnels. We also hosted a professor from the University of Puerto Rico-Utuado for her sabbatical visit to develop collaborative research and extension projects on pest management in vegetable production under high tunnels. We continued to incorporate research findings from this project into teaching modules of undergraduate courses on organic and sustainable crop production at the University of Florida. We also continued to involve undergraduate students in project research activities to help them understand different aspects of organic crop production and high tunnel systems and develop multifaceted skills in field and laboratory research. Interdisciplinary training opportunities have been offered to graduate students who are active members of this project. Their research activities are interconnected through field trials that serve multiple objectives across different disciplines such as vegetable production and crop nutrition, soil science, plant pathology and entomology, and food and resource economics. They have been participating in our monthly project meetings to present their research progress. One of the graduate students is also playing a major role in leading the effort of organizing grower assessment of research trials and advisory panel meetings. How have the results been disseminated to communities of interest? We recruited 3 additional members for the advisory panel (2 organic producers and 1 agricultural service provider) and held the second advisory panel meeting on 3 Mar. 2020, in Tifton, GA. The advisory panel meeting report and Powerpoint presentation were distributed to the research team and advisory panel members. The meeting report has been posted on our project webpage. We recruited 6 participants and conducted our second research assessment on 5 Nov. 2019, in Citra, FL at the University of Florida Plant Science Research and Education Unit. The research assessment report was distributed to the research team, participants, and posted on the project webpage. We updated the project website throughout the year and continued to take photos of field research for the website and the development of the virtual field day videos and topical videos showcasing research activities of this project. Prior to the COVID-19 pandemic, we were able to visit or meet with growers to discuss project findings. County-level extension meetings were conducted in Georgia to disseminate project results, including the meeting in Blairsville on 13 Feb. 2020 (20 attendees) and the meeting in Clayton on 14 Feb. 2020 (35 attendees). During the pandemic, in addition to direct communication with stakeholders via zoom video conferencing and phone calls (one on one interface), we disseminated project results through newsletters and extension webinars. Some of our team members have also included relevant project results in their invited guest lectures to undergraduate and graduate students in the classroom. During this reporting period, we presented project information at various conferences and stakeholder meetings such as the American Society for Horticultural Science Annual Conference, the Southern Sustainable Agriculture Working Group Annual Conference, the Mid-Atlantic Fruit and Vegetable Convention, and the Florida A&M University Center for Biological Control advisory committee meeting. What do you plan to do during the next reporting period to accomplish the goals? During the next reporting period, we will complete the third-year high tunnel organic vegetable production system research trials at the University of Georgia and the University of Florida. At the Florida A&M University research site, we plan to continue the lettuce cultivar assessment year-round inside the top vented screenhouse structure in comparison with open field production. We will continue to monitor plant diseases and population of pests and beneficials during different crop cycles throughout the season. With information obtained from another year, we will create extension documents about high tunnel disease and pest management for organic crop production. We will also initiate, conduct, and analyze experiments using the "push-pull" strategy complemented with the use of a commercial mix of beneficial flowering plants, to control insect pests in organic vegetables in high tunnels. The "pull" component will include testing of green leaf volatiles. All research trial data will be collected on a regular basis and data analyses will be conducted in a timely manner. In addition, we will continue the economic cost and benefit analysis during the next reporting period. The high tunnel budget sheet will be improved to account for the time value of money (by calculating the net present value) when using high tunnels for organic vegetable production. Moreover, survey instruments will be developed for identifying key factors that influence high tunnel adoption among farmers. We will continue our monthly project meetings to help engage all team members and facilitate project coordination and development. With respect to project assessment and outreach, we will recruit 2 additional members for the advisory panel. We will host one virtual advisory panel meeting and two virtual research assessments. We plan to host an in-person research assessment on the high tunnel organic tomato production trial in 2021 if permitted with COVID-19 restrictions. A virtual assessment will be held if we are unable to host an in-person assessment. We also plan to produce four virtual field day videos showcasing some research treatments from the high tunnel organic vegetable production trials in 2018-2019. We will continue to take photos of the biological research for our project webpage and those photos will be used to develop virtual field days and topical videos showcasing this project. We will continue to disseminate research results through presentations at professional conferences and meetings with growers and extension agents. The project team will explore different tools including the

effective online platform to help facilitate outreach activities. We also plan to produce extension publications and submit research manuscripts for publication in peer-reviewed journals.

2020/09 TO 2021/08 Target Audience: The target audience includes certified organic vegetable growers, transitional organic producers, growers who are interested in organic vegetable production, high tunnel growers, producers interested in using high tunnels for organic vegetable crops, minority and limited-resource growers, beginning farmers and ranchers interested in organic production, small farm and urban farm producers, scientists and researchers, educators, extension personnel, agricultural service providers, agricultural consultants, industry representatives, undergraduate and graduate students, high school students interested in agricultural science, home gardeners, backyard growers, and the general public. Changes/Problems: The COVID-19 pandemic continued to present challenges to completing planned research and outreach activities during this reporting period. Some field research experiments and in-person outreach activities had to be cancelled and the grower survey had to be postponed. We augmented our planned activities to comply with research restrictions by reworking the activity to a hybrid or virtual format. We conducted the third advisory panel meeting virtually via Zoom. We conducted the third research assessment in a hybrid format where participants completed their field observations in person and participated in a facilitated discussion via Zoom. We conducted the fourth research assessment in a virtual format where participants completed their observations using photos and entering their responses in an online instrument and participated in a facilitated discussion via Zoom. We will produce two additional virtual field day videos to replace field days we were unable to host due to COVID-19 restrictions. We were unable to conduct on-farm trials to date due to both COVID-19 restrictions and not wanting to burden farmers with conducting research during such a stressful time. We will now complete our on-farm trials focusing on pest and disease incidence and management from Nov. 2021 through May 2022 at five farms throughout Florida. What opportunities for training and professional development has the project provided? During this reporting period, our project continued to provide diverse opportunities for training and professional development. At the Florida A&M University Research and Extension Center, research farm tours were offered to beginning farmers. Attendees learned about up-to-date research information on leaf lettuce production in a high tunnel, organic production, barriers to organic leaf lettuce production, plant bolting concerns, and key components of an in-ground experimental plot design. Through the partnership with our collaborator at the University of Puerto Rico-Utuado, we presented at the online high tunnel workshop to specialty crop growers in Puerto Rico. We also discussed our research findings at two other workshops on sustainable vegetable production and protected agriculture organized by University of Florida researchers and extension agents. In addition, we conducted a virtual high tunnel tomato cultivar assessment that involved a diverse group of organic farmers and vegetable growers. We also continued to incorporate research findings from this project into teaching modules of undergraduate courses on organic and sustainable crop production at the University of Florida. We recruited a number of undergraduate students to participate in project research activities to gain a basic understanding of organic vegetable production in high tunnels and develop multifaceted skills in field and laboratory research. Interdisciplinary training opportunities have been offered to graduate students in different programs such as horticultural sciences, plant pathology, entomology, food and resource economics, and interdisciplinary ecology. Their research activities are interconnected through field trials and teamwork that serve multiple objectives across different disciplines. The graduate students have been presenting their research progress during our monthly project meetings and they are also actively involved in project outreach programs. One of the graduate students has been playing a major role in leading the effort of organizing grower assessment of research trials and advisory panel meetings. How have the results been disseminated to communities of interest? During this reporting period, we presented project information at various conferences and stakeholder meetings such as the American Society for Horticultural Science Annual Conference and the Southeast Regional Fruit & Vegetable Conference. Research findings were also disseminated through presentations at various workshops, research farm tours, local county level meetings with extension agents and growers, newsletters, and the project webpage. Research and extension publications have been produced. We updated the project webpage throughout the year and continued to take photos of field research for the webpage and the development of the virtual field day videos and topical videos showcasing the research activities. Up-to-date project results were also presented at our annual advisory panel meeting. We recruited five additional members for the advisory panel (three Extension agents and two agricultural service providers) and held the third advisory panel meeting virtually via Zoom on 3 Mar. 2021. Nine participants were recruited to help conduct our third research assessment on 16 Mar. 2021 at PSREU in Citra, FL. We also recruited eight participants and conducted our fourth research assessment on 22 Apr. 2021 virtually via Zoom. The third advisory panel meeting report was distributed to the research team and advisory panel members. The third and fourth research assessment reports were distributed to the research team and stakeholder participants. All the reports are posted on our project webpage. What do you plan to do during the next reporting period to accomplish the goals? We plan to complete this project during the next reporting period. The high tunnel lettuce cultivar evaluation trials will be continued at the Florida A&M University research site in Quincy, FL. We will demonstrate the "push-pull" strategy complemented with the use of a commercial mix

of beneficial flowering plants, to control insect pests in organic vegetables in high tunnels. All the remaining research samples will be processed, and data analysis and synthesis will be performed for all the research trials conducted at different sites in Florida and Georgia. We will obtain more data on the research trials and continue the economic cost and benefit analysis. The high tunnel survey instrument will be finalized and distributed to growers in Georgia and Florida for identifying the factors that influence high tunnel adoption among farmers. Research manuscripts will be submitted for publication in peer-reviewed journals and extension publications on various aspects of high tunnel organic vegetable production systems will be prepared. We plan to present project findings at professional conferences and grower meetings and disseminate research results to organic producers through a variety of extension activities such as the 2022 High Tunnel Workshops and Alternative Crop Enterprise programs. We will host the final advisory panel meeting virtually via Zoom. We also plan to host a virtual tomato cultivar assessment using the data and photos from the 2020 high tunnel organic tomato trial in Watkinsville, GA. We will produce four virtual field day videos showcasing four treatments from the high tunnel organic tomato trials conducted in Citra, FL. We will produce one virtual field day video showcasing the 2020 high tunnel organic tomato cultivar trial in Watkinsville, GA. We also plan to produce eight topical videos showcasing some of the project findings. Additionally, we will complete on-farm trials monitoring pest and disease incidence and management from Nov. 2021 through May 2022 at five farms in Florida.

2017/09 TO 2018/08 Target Audience: The target audience includes certified organic vegetable growers, transitional organic producers, growers who are interested in organic vegetable production, high tunnel growers, producers interested in using high tunnels for organic vegetable crops, minority and resource-limited growers, small farm and urban farm producers, researchers and educators, extension personnel, service providers, agricultural consultants, industry representatives, and the general public. Changes/Problems: Our project timeline had to be adjusted due to the delay of funding disbursements and project account establishment for all the PIs. High tunnel installation was not completed as initially scheduled because of the funding issue and some other problems encountered during the construction process, which caused a delay in starting the research trials. For example, the number of planting dates had to be reduced for the high tunnel tomato trial in FL, and the research trials at the University of Georgia were not able to be initiated until Fall 2018. We also encountered some personnel change at the University of Georgia in winter 2018 as one of the co-PI left the university. However, it did not cause any negative impact on the project as another co-PI at the University of Georgia was able to take the lead to complete all the project activities. What opportunities for training and professional development has the project provided? Systematic training opportunities have been provided to graduate students who participated in the project by leading and conducting specific research activities such as experimental design, implementation of research experiment, IPM and scouting, disease diagnosis, data collection and statistical analysis, and report preparation. Moreover, the graduate students gained insightful experiences in interdisciplinary collaborations by attending the project meetings and working with the project team. We also hosted an undergraduate summer research intern at the University of Florida to engage the student in carrying out an independent study as part of the high tunnel organic tomato production trial. Other undergraduate research assistants involved in the project were also well engaged during the research trials to help grow their interest in scientific research with basic skill development. Some of the project results have been incorporated into the class content for undergraduate and graduate courses on organic horticulture and biological control of arthropods and weeds at the University of Florida and Florida A&M University. How have the results been disseminated to communities of interest? We invited our stakeholder collaborators to visit the high tunnel tomato planting date trial during the production season at PSREU (Citra, FL). The project has been discussed during county-level meetings with growers in GA. Project information was also disseminated at science festival, grower conference, workshop, and field day, including Tallahassee Science Festival, Tallahassee, FL (October 28, 2017), Southeast Regional Fruit & Vegetable Conference, Savannah, GA (January 12, 2018), Vineyard Management, IPM and Pesticide Safety Workshop, Florida A&M University Center for Viticulture and Small Fruit Research, Tallahassee, FL (February 21, 2018), and Spring Farm Fest Field Day, Florida A&M University Research and Extension Center, Quincy, FL (June 9, 2018). What do you plan to do during the next reporting period to accomplish the goals? Some experimental samples and research data from this project period will continue to be analyzed and compiled during the next reporting period and research findings will be presented at the professional conferences and meetings with growers and extension agents. We will continue our monthly project meetings to help with project coordination and implementation. Research trials and activities planned for different objectives will be performed during the 2018-2019 production season, and project dissemination activities such as workshop and field day will be planned accordingly. We will assemble our advisory panel and host our first advisory panel meeting. Our first research assessment will also be conducted in Citra, FL during the next reporting period. We will continue to take photos of the biological research trials and begin to produce videos for project assessment and dissemination. In addition, we plan to create and launch our virtual field day.

## IMPACT

2018/09 TO 2019/08 What was accomplished under these goals? Research objectives 1, 2, and 3: Assess the efficacy of environmental control measures on organic vegetable production under high tunnels; Optimize planting time for high-tunnel produced organic vegetables; Determine the influence of integrated nutrient management practices on nutrient use efficiency and soil quality in high tunnel organic vegetable production. High tunnels were prepared and mist systems installed in Aug. 2018 in two certified organic high tunnels in Watkinsville, GA. One high tunnel received shade cloth, while the other did not. Within each high tunnel there were two planting dates and two treatments (misted and non-misted) arranged in a randomized complete block design with four replications. Basil, lettuce, and arugula were grown in each treatment at each planting date. Crops were harvested through Nov. 2018 with yield, nutrient, and microclimate data collected. Year 2 of this study is to be planted in Sept. 2019. An additional trial featuring shade cloth for summer-grown lettuce was conducted in June/July 2019. We determined that shade cloth during the summer months allowed for the production of lettuce in a high tunnel compared to outdoor production, which was not commercially viable. This project was conducted in partnership with Johnny's Seeds (supplied germplasm). In Tifton, GA, tomato and lettuce transplants were started and planted in Oct. 2018 for production through the spring of 2019. Yield and quality data were obtained from all plantings. In addition, tomatoes were grown under different shade cloth colors in summer 2019 and research is currently ongoing in Tifton, GA. The tropical greenhouse structure at the Florida A&M University Research and Extension Center (Quincy) was destructed by Hurricane Michael in Oct. 2018. Hurricane force winds that entered through the top vent roofing component of the structure were strong enough to lift the roof assembly causing the rooftop to rise and the structure endwalls to accordion inwards and unto itself. After close examination of the structure collapse, it was determined that the row of center column posts supporting the roof assembly had not been properly secured. Images of the structure collapse were shared with the structure manufacturer and product installers and after their internal review, the manufacturer agreed to take down and replace the greenhouse structure at no cost. The new structure was completed by Mar. 2019. The integrated nutrient management experiment was established in a 3-bay high tunnel system on certified organic land at the University of Florida Plant Science Research and Education Unit (PSREU) in Citra, FL. A split-split plot design with 3 replications was used with weedy fallow and cowpea planting prior to the vegetable season in the whole plots, pre-plant application of solid organic fertilizer (Nature Safe 10-2-8) vs. in-season fertigation with liquid organic fertilizer (Aqua Power 5-1-1) for nitrogen fertilization as the subplot factor, and application of different types of composts (i.e., yard waste-based compost, cow manure-based compost, vermicompost, and no compost) as the sub-subplot factor. Cowpea was planted in Aug. 2018, followed by 'Mei Qing' pac choi transplanting in Oct. 2018 and harvest in mid-Nov. 'Corvair' spinach was seeded in the same treatment plots 3 days after pac choi harvest without further addition of compost or organic fertilizer. Beefsteak tomato 'Skyway' was transplanted into the high tunnel plots in late Jan. 2019, with the final harvest completed in mid-June. An additional split of the sub-subplot was used to include both grafted and non-grafted tomato plants in the study. The solid fertilizer treatment was also changed to 20% preplant with 80% in-season fertilization through side dressing. Cover crop biomass and nutrient input, vegetable plant growth, yield, aboveground nutrient accumulation, soil nitrogen availability and dynamics, and fruit quality attributes were assessed during the crop production cycles. Overall, the impact of compost outweighed the cover crop effect and liquid fertilization produced higher crop yield than solid fertilization. Grafted tomato plants with the 'Multifort' rootstock led to a significant increase in total fruit yield compared with non-grafted plants. Research objectives 4 and 5: Monitor and characterize plant pathogens infecting high priority organic high tunnel crops; Monitor population of arthropod pests and beneficials in high tunnel organic vegetable cropping systems. Samples were collected from the high tunnel organic vegetable research plots at PSREU in Citra, FL, which are being tested for soil diseases. Foliar disease problems were monitored and managed throughout the production season, and plant materials were sampled for pathogen diagnosis. Powdery mildew was the main foliar disease observed during the tomato production trial. Yellow sticky cards, sweep nets, and visual scouting were used to monitor pest and beneficial populations in the high tunnel plots throughout the crop season. Thrips, aphids, and whiteflies were found during the trials, while lady beetles, minute pirate bugs, and some parasitoid wasps were also observed. Information documented to date will be used to guide the survey in the coming growing seasons. Objective 6: Develop cultural and biological alternatives for managing whiteflies and aphids. Tomato seedlings of six different cultivars were planted in June 2019 in a tropical greenhouse at the Florida A&M University Research and Extension Center, Quincy, FL. In this study, the "push" component of the push-pull strategy included potted repellent plants of citronella, society garlic, and lemon grass. Attractive refuge plants such as marigold ('French Marigold') and potted basil ('African Blue') were placed on the edges of the greenhouse. These plants will enhance populations of beneficial insects that may reduce the numbers of whiteflies, thrips, and aphids. Population densities of insects throughout the season were monitored by taking weekly samples of sticky traps and leaf counts. Sweetpotato whiteflies, aphids, and thrips were the common insect pests found in the tomato plants, and

yellow striped armyworms were observed to feed on the tomato fruit. The natural enemies of the insect pests collected were mainly the minute pirate bug, *Orius* spp. and whitefly parasites, *Encarsia* spp. and *Eretmocerus* spp. Objective 7: Analyze on-farm economic viability of high tunnel organic vegetable production and identify the factors influencing high tunnel adoption among organic growers. We developed the budget to estimate the costs of high tunnel systems including the construction and maintenance costs. The estimates are based on the data from project co-PIs who have built high tunnels on their experimental stations and the secondary data collected online. We are currently conducting the economics analysis of vegetable production under high tunnels using the data from an organic tomato trial that was conducted at PSREU in Citra, FL during Jan. to July 2018. We estimated the costs of the whole production cycle including the harvests and calculated the total costs and net returns for different treatments (early vs. late planting time, grafted vs. non-grafted plants of two tomato cultivars) per acre. We will continue the economic analysis of the data from the pac choi, spinach, and tomato trials conducted during 2018-2019 seasons. The established budget sheet will then be sent to collaborators of the project to collect more information and for verification. The ultimate goal is to estimate the cost and return of using high tunnels for organic vegetable production over multiple seasons during the lifespan of the high tunnel.

**\*\*PUBLICATIONS (not previously reported):\*\*** 2018/09 TO 2019/08 1. Type: Conference Papers and Presentations Status: Accepted Year Published: 2019 Citation: Laur, S. and T. Coolong. 2019. Impact of shade cloth and a fogging system on microclimate in an organic high tunnel. Southern Region American Society for Horticultural Science Annual Conference, Birmingham, AL. 2. Type: Conference Papers and Presentations Status: Accepted Year Published: 2019 Citation: Laur, S. and T. Coolong. 2019. The effects of microclimate modifications on crop yield and quality in organic high tunnels. American Society for Horticultural Science Annual Conference, Las Vegas, NV. 3. Type: Conference Papers and Presentations Status: Accepted Year Published: 2019 Citation: Tian, S., X. Zhao, and Z. Black. 2019. Effects of leguminous cover crop, compost, and organic fertilizer on high tunnel organic production of pac choi and spinach. American Society for Horticultural Science Annual Conference, Las Vegas, NV. 4. Type: Conference Papers and Presentations Status: Accepted Year Published: 2019 Citation: Zhao, X. 2019. Addressing challenges of high tunnel organic vegetable production in subtropical Florida. Workshop on multiregional assessment of opportunities and challenges of high tunnel organic crop. American Society for Horticultural Science Annual Conference, Las Vegas, NV. 5. Type: Conference Papers and Presentations Status: Accepted Year Published: 2018 Citation: Sattanno, K., M.E. Swisher, J. Colee, X. Zhao, Z. Gao, and Z. Black. 2018. Growing high tunnel use for organic vegetable production in the Southeast. American Society for Horticultural Science Annual Conference, Washington, DC.

2019/09 TO 2020/08 What was accomplished under these goals? Research objectives 1, 2, and 3: Assess the efficacy of environmental control measures on organic vegetable production under high tunnels; Optimize planting time for high-tunnel produced organic vegetables; Determine the influence of integrated nutrient management practices on nutrient use efficiency and soil quality in high tunnel organic vegetable production. At the University of Georgia research site in Watkinsville, the second-year study focused on high tunnel environmental control measures was completed. Use of shade cloth and misting and planting dates were examined with respect to their impacts on high tunnel organic production of basil, lettuce, and arugula. Crops were harvested through Nov. 2019 with yield, nutrient, and microclimate data collected. The results of this two-year trial are in the process of being submitted for publication in HortTechnology. At the research site in Tifton, GA, tomato seedlings were transplanted about every three weeks from 1 Oct. 2019 to 2 Jan. 2020 and lettuce was planted from 1 Oct. 2019 to 13 Feb. 2020 for the high tunnel planting time study. Microenvironmental data, plant mineral content, and plant biomass were determined. Another high tunnel trial assessed the effects of different types of plastic mulch and shade cloth on organic tomato production. Tomato was transplanted in Aug. 2019 on black vs. white plastic mulch, and high tunnels were covered with black vs. silver shade cloth. Microenvironment and plant growth data were collected. An additional trial featuring high tunnel-grown heirloom-type tomatoes was conducted in Georgia in spring 2020 in partnership with Johnny's Selected Seeds. At the Florida A&M University research site in Quincy, following the replacement of the top vented greenhouse structure that resulted from hurricane Michael on Oct. 2018, research and extension activities resumed for this reporting period. The new structure was fitted with smart sensors to measure soil moisture, temperature, and relative humidity inside and outside the structure. Fifteen leaf lettuce cultivars were evaluated inside the greenhouse structure for overall plant size, plant vigor, plant health, bolting, and pest observations, with a demonstration control plot in the open field. Three evaluation cycles were completed in 2020: 4 Feb. to 15 May, 20 April to 15 July, and 16 July to 9 Sep. Eight cultivars grew beyond their catalog "days of maturity" period prior to bolting inside the greenhouse structure, with the extra period ranging from 10 to 30 days. In the open field, the extra growing period ranged from 21 to 38 days. Overall, leaf lettuce cultivars in the greenhouse structure bolted on average 4.3 days earlier than the open field leaf lettuce. The second-year study on integrated nutrient management in high tunnel organic vegetable production was completed during this reporting period. The trials were conducted at the University of Florida Plant Science Research and Education Unit (PSREU) in Citra, involving the planting of cowpea as a summer cover crop, use of different types of compost products, and

application of different organic fertilizers. Pac choy ('Mei Qing Choi') was transplanted on 11 Oct. 2019 and harvested on 12 Nov. 2019. Lettuce ('Outredgeous') was direct seeded on 13 Nov. 2019 and baby lettuce was harvested on 16 Dec. 2019 following the pac choy crop, without any additional organic amendment or nutrient input. Beefsteak tomato ('Skyway') seedlings were transplanted on 19 Dec. 2019 and the final harvest was completed in mid-June 2020. Grafted plants with the 'Estamino' rootstock were also tested in the tomato trial. In addition to crop growth, yield, and plant nutrient status, soil sampling and anion exchange membrane methods were used to monitor soil available nitrogen dynamics during the season. Quality attributes of leafy greens and tomato fruit were also analyzed, and soil health tests were performed after the tomato season. Overall, the cowpea cover crop did not show a significant impact on vegetable crop yield performance. Liquid fertilization tended to increase crop yields compared with the use of granular organic fertilizer, while yard waste based-compost and cow manure-based compost increased the yield of pac choy and tomato, respectively, in comparison with the no compost control. Grafting improved tomato fruit yield regardless of nutrient management practices.

Research objectives 4 and 5: Monitor and characterize plant pathogens infecting high priority organic high tunnel crops; Monitor population of arthropod pests and beneficials in high tunnel organic vegetable cropping systems. Plant diseases were monitored throughout the high tunnel organic crop production trials at PSREU in Citra, FL. Diseased plant tissue samples were collected for pathogen identification. Diseases of tomato included *Rhizoctonia* crown rot, southern stem rot, tomato leaf mold, and tobacco mosaic virus. Isolates were collected when possible for these diseases and a focus has been made to write up recommendations related to organic production and disease management. Data were also collected throughout all crop cycles in the high tunnel regarding the population of pests and beneficials. Over 10,000 specimens were identified from yellow sticky cards and through visual observation. Objective 6: Develop cultural and biological alternatives for managing whiteflies and aphids. Various varieties of leafy greens were planted inside the tropical screenhouse structure (Quincy, FL). The "push" component of the push-pull strategy included potted repellent plants of mustard ('Giant Red', 'Caliente', and 'Nemat') and garlic chives. Attractive flowering plants such as marigold ('French marigold'), sweet alyssum, and potted basil ('African blue') were placed on the edges of the screenhouse. Commercial "preda-lure" were placed near the flowering plants. These plants and lures will enhance populations of beneficial insects that may reduce the numbers of insect pests. As part of the "pull" component, different concentrations of green leaf volatiles (GLVs) were tested as attractants of the sweetpotato whitefly. The GLV previously tested in a greenhouse was the leaf acetate (cis-3-hexenyl acetate). In the laboratory using an odor-detecting equipment, leaf acetate (cis-3-hexenyl acetate) and leaf alcohol (cis-3-hexen-1-ol) were tested. Preliminary results showed that the leaf acetate (cis-3-hexenyl acetate) seemed to be attractive to sweetpotato whitefly. Population densities of insects throughout the season were monitored by taking weekly samples of sticky traps, and leaf counts. Data from the latter sampling methods continue to be processed and recorded. Preliminary results indicate that sweetpotato whiteflies, aphids, and thrips were the common insect pests. The beneficial insects or natural enemies of the insect pests collected were mainly the lacewing and whitefly parasites, *Encarsia* spp. and *Eretmocerus* spp.

Objective 7: Analyze on-farm economic viability of high tunnel organic vegetable production and identify the factors influencing high tunnel adoption among organic growers. We improved the budget to estimate the costs of high tunnel systems, including the construction and maintenance costs. The estimates are based on the data from researchers on the team who have installed high tunnels for research and extension trials and the secondary data collected online. During this reporting period, we finished the economic analysis of high tunnel organic production of pac choy, spinach, and tomato using the data from research trials conducted at PSREU (Citra, FL) during the 2018-2019 production season. We estimated the cost of the whole production process (including pre-planting, production, and post-planting) and calculated the annual total cost and net return for growing organic vegetables in high tunnels. \*\*PUBLICATIONS (not previously reported):\*\* 2019/09 TO 2020/08

1. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Coolong, T, S. Laur, K. Cassity-Duffey, and M. Cabrera. 2020. Evaluating nitrogen mineralization from cover crops grown in high tunnels. American Society for Horticultural Science Annual Conference (virtual).
2. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Díaz-Pérez, J.C., T. Coolong, and J. Bautista. 2020. Planting date affects leaf mineral nutrients and plant weight in organic lettuce grown in high tunnels. American Society for Horticultural Science Annual Conference (virtual).
3. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Donovan, M., M.E. Swisher, K. Sattanno, and X. Zhao. 2020. Nutrient management regime grower assessment of organic pak choy in a high tunnel. American Society for Horticultural Science Annual Conference (virtual).
4. Type: Conference Papers and Presentations Status: Other Year Published: 2020 Citation: Donovan, M., M.E. Swisher, K. Sattanno, and X. Zhao. 2020. Nutrient management regime assessment of organic tomatoes raised in a high tunnel. Southern Sustainable Agriculture Working Group Annual Conference, Little Rock, AR.
5. Type: Conference Papers and Presentations Status: Other Year Published: 2020 Citation: Donovan, M., M.E. Swisher, K. Sattanno, and X. Zhao. 2020. Nutrient management in high tunnels: Grower perspectives on experimental design. 75th Anniversary Event for the Board on Agriculture and Natural Resources (BANR) of the National Academies (NASEM), Gainesville, FL.
6. Type: Conference Papers and Presentations Status: Published Year Published:

2020 Citation: Tian, S., X. Zhao, and Z. Black. 2020. Effects of integrated nutrient management on high tunnel organic vegetable production. American Society for Horticultural Science Annual Conference (virtual). 7. Type: Conference Papers and Presentations Status: Other Year Published: 2020 Citation: Zhao, X., C.J. Frey, J.K. Brecht, and S. Tian. 2020. Integrated high tunnel systems for improving organic vegetable production. Mid-Atlantic Fruit and Vegetable Convention, Hershey, PA. 8. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Zhao, X., M.E. Swisher, N.S. Dufault, A.C. Hodges, Z. Gao, A. Bolques, J.C. Legaspi, T. Coolong, and J.C. Díaz-Pérez. 2020. An integrated multi-institutional project to promote high tunnel organic vegetable production in the Southeast. American Society for Horticultural Science Annual Conference (virtual). 9. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Tian, S., X. Zhao, and J. Brecht. 2020. Quality attributes of pac choi and baby lettuce under high tunnel organic production as affected by nutrient management practices. American Society for Horticultural Science Annual Conference (virtual).

2020/09 TO 2021/08 What was accomplished under these goals? Research objectives 1, 2, and 3: Assess the efficacy of environmental control measures on organic vegetable production under high tunnels; Optimize planting time for high-tunnel produced organic vegetables; Determine the influence of integrated nutrient management practices on nutrient use efficiency and soil quality in high tunnel organic vegetable production. At the University of Georgia research site in Tifton, research trials were continued to determine the influence of shade and plastic mulch treatments on crop growth, yield, and quality, and environmental conditions of tomato and lettuce grown in organically managed high tunnels. Different planting dates were also examined for high tunnel tomato production toward optimizing crop productivity and season extension. The graduate student leading the work on assessing the effects of shade cloth in combination with over-head misting on growth of organic spinach and arugula under high tunnels at the University of Georgia research site in Watkinsville received her M.S. degree in Aug. 2020. She has taken a position in Cooperative Extension as a County Agent in North Carolina. At the Florida A&M University research site in Quincy, the research work was focused on comparing the production of different leafy greens in a top vented structure in North Florida. Growth, yield, and quality of organically grown leaf lettuce in a tropical screen house high tunnel and the open field were evaluated during this reporting period. Four evaluation cycles were achieved, including 17 Nov. to 24 Dec. 2020, 5 Mar. to 25 May 2021, 5 May to 5 July 2021, and 23 June to 25 Aug. 2021. Eleven lettuce cultivars were evaluated with three replications in a randomized complete block design. Lettuce seedlings were planted in the high tunnel and open field 37 days after seeding in the greenhouse. Data collection began three weeks after planting in the high tunnel and open field. Assessment of plant performance parameters showed that the greatest percentage of heads ranked in the average category was 60.8% in the open field and 57.3% in the high tunnel. Plant vigor ratings were also greatest in the moderate category, with 59.7% in the open field and 54.5% in the high tunnel. Healthier plants were observed in the high tunnel, where 86.3% were in the very healthy category. Conversely, only 51.6% of the plants in the open field were in the very healthy category. Early bolting cultivars included loose leaf lettuce 'Vulcan' in the open field and 'Green Star', 'Star Fighter', and 'Vulcan' in the high tunnel. Late bolting cultivars included summer crisp lettuce 'Nevada' and 'Magenta' and oakleaf lettuce 'Panned' in both production systems. By the end of this reporting period, we have completed the three-year study at the University of Florida Plant Science Research and Education Unit (PSREU) in Citra with an emphasis on evaluating integrated nutrient management practices for high tunnel organic vegetable production. Findings from the third year study demonstrated that the cowpea cover crop had little influence on improving the yield of leafy greens and tomato. In the leafy green season, weekly liquid fertilization led to a significantly higher yield of pac choi than the application of preplant granular fertilizer, while the yard waste based-compost treatment tended to enhance the total yield of pac choi and the subsequent baby lettuce crop compared with the no compost control. For the tomato season, weekly application of the liquid organic fertilizer resulted in significantly higher total and marketable yield and fruit numbers in contrast to using the granular organic fertilizer at preplant and through sidedressing. Grafted tomato plants produced significantly higher fruit number and yield compared with the non-grafted plants. The soil samples were collected at the end of tomato season to assess soil health indicators. No significant differences were found between the cowpea cover crop treatment and the weedy fallow control. Granular fertilization exhibited the potential for improving the overall fertility score in comparison with the liquid fertilizer treatment. The yard waste based-compost and cow manure-based compost treatments helped increase soil organic matter content and enhance aggregate stability and soil health and overall fertility scores while reducing dry soil bulk density. Vegetable samples for quality assessment are also being analyzed with data processing ongoing. Research objectives 4 and 5: Monitor and characterize plant pathogens infecting high priority organic high tunnel crops; Monitor population of arthropod pests and beneficials in high tunnel organic vegetable cropping systems. During this reporting period, we continued to monitor plant diseases during the high tunnel organic vegetable production trials conducted at PSREU in Citra, FL. An extension publication is being prepared with respect to identifying major tomato disease problems in organic high tunnel systems. Pest and beneficial insect monitoring data were also collected for the high tunnel experiments at PSREU, on at least 30 data collection points during

the reporting period. Over 10,000 specimens were identified from yellow sticky cards and through visual observation. A data synthesis table was constructed to highlight the taxa summary of pest and beneficial insects identified in the organically managed high tunnel during the reporting period. Objective 6: Develop cultural and biological alternatives for managing whiteflies and aphids. We continued to process the data from previous seasons collected in high tunnels in Quincy, FL and Tifton, GA. Preliminary results from yellow stick trap samples collected in a tomato crop in a high tunnel at the University of Georgia in Tifton, GA from Mar. to Apr. 2019 showed that the major and most abundant insect pest was thrips followed by aphids and sweetpotato whitefly. A few whitefly parasites, *Encarsia* spp. and *Eretmocerus* spp. were collected. Objective 7: Analyze on-farm economic viability of high tunnel organic vegetable production and identify the factors influencing high tunnel adoption among organic growers. We developed R coding to conduct the cost and benefit analysis of organic vegetable production under high tunnels using the on-station research trial data from the past two years (2018-2019 and 2019-2020) with respect to organic tomato, pac choi, and spinach. We estimated the annual total cost and net return for growing organic vegetables under high tunnels. Sensitivity analysis was also performed to determine the effect of grafted transplant price and tomato market price on the economic return of tomato (grafted vs. non-grafted) production in organically managed high tunnels. In addition, we developed a draft of the high tunnel grower survey aimed at determining organic growers' perception and attitude toward high tunnel adoption for vegetable production. \*\*PUBLICATIONS (not previously reported):\*\* 2020/09 TO 2021/08 1. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Bag, S., J. Bautista, G. Gunawan, M. Bashyal, T.W. Coolong, H. Milner, and J.C. Díaz-Pérez. 2021. Organic tomato grown in high tunnels as affected by shade net and plastic mulch color. American Society for Horticultural Science Annual Conference, Denver, CO. (virtual presentation) 2. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Donovan, M., M.E. Swisher, K. Sattanno, and X. Zhao. 2021. Grower assessment of organic tomato nutrient management factors in a high tunnel. American Society for Horticultural Science Annual Conference, Denver, CO. (virtual presentation) 3. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Tian, S., X. Zhao, and J. Brecht. 2021. Assessing grafting and integrated nutrient management practices, including cover crop, composts, and organic fertilizers, on organic high tunnel tomato production. American Society for Horticultural Science Annual Conference, Denver, CO. (virtual presentation) 4. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Zhao, R., Y. Nian, Z. Gao, X. Zhao, and S. Tian. 2021. Cost and benefit analysis of grafted tomato production in organically managed high tunnels. American Society for Horticultural Science Annual Conference, Denver, CO. (virtual presentation) 5. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Zhao, X. 2021. Soil and nutrient management for high tunnel organic vegetable production: Case studies in Florida. Southeast Regional Fruit & Vegetable Conference, Savannah, GA. (virtual presentation) 6. Type: Journal Articles Status: Published Year Published: 2021 Citation: Laur, S., A.L.B.R. da Silva, J.C. Díaz-Pérez, and T. Coolong. 2021. Impact of shade and fogging on high tunnel production and mineral content of organically grown lettuce, basil, and arugula in Georgia. *Agriculture* 11:625. 7. Type: Other Status: Published Year Published: 2021 Citation: Laur, S., M. Donovan, J.C. Díaz-Pérez, and T. Coolong. 2021. Extending the growing season for lettuce in Georgia using shade cloth and high tunnels. University of Georgia Extension Circular 1241. 8. Type: Other Status: Other Year Published: 2021 Citation: Zhao, X. 2021. Integrated practices for improving organic vegetable production. Sustainable Vegetable Production Workshop, Citra, FL. 9. Type: Other Status: Other Year Published: 2021 Citation: Zhao, X. 2021. Organic tomato production in high tunnels. Virtual Workshop on Vegetable Production in Greenhouses & High Tunnels (FL). 10. Type: Other Status: Other Year Published: 2021 Citation: Zhao, X. 2021. High tunnel systems for improving organic vegetable production. Virtual Workshop on High Tunnel Production Systems (PR).

2017/09 TO 2018/08 What was accomplished under these goals? Research objectives 1, 2, and 3: Assess the efficacy of environmental control measures on organic vegetable production under high tunnels; Optimize planting time for high-tunnel produced organic vegetables; Determine the influence of integrated nutrient management practices on nutrient use efficiency and soil quality in high tunnel organic vegetable production. High tunnel construction took place at the University of Florida, Florida A&M University, and University of Georgia research sites at the beginning of the project before carrying out the high tunnel organic vegetable production studies. The research trial planting schedules were adjusted accordingly to cope with the delay encountered in high tunnel installation. Monthly project meetings were used as an effective management tool to facilitate the development of this multi-regional integrated project. High tunnels were prepared and mist systems installed in August 2018 in two certified organic high tunnels in Watkinsville, GA. One high tunnel received shade cloth, while the other did not. Within each high tunnel there will be two planting dates and two treatments (misted and non-misted) arranged in a randomized complete block design with four replications. Six vegetable crops (arugula, basil, carrot, spinach, beets, and cilantro) will be planted during the fall trial reflecting the range of crops grown by local growers. Plants will be transplanted/seeded in tunnels in late September and early October to reflect early fall planting dates experiencing heat stress. Three standard 30 ft x 72 ft high tunnels were built on a certified

organic research site in spring and summer 2018 at the University of Georgia in Tifton, GA in order to start the planting date research in fall 2018. Tomato and lettuce transplants were started and will be planted in October 2018. A PhD student has started in August 2018 to lead efforts for this objective. A 3-bay high tunnel (30 ft × 84 ft each bay) was installed on the certified organic land at the University of Florida Plant Science Research and Education Unit (PSREU) in Citra, FL in fall 2017 for the spring tomato planting date trial. Two grape tomato cultivars, including one determinate cultivar and one indeterminate cultivar, were used and plants were transplanted on January 29 and March 9, 2018, respectively. Both grafted (with 3 different tomato hybrid rootstocks) and non-grafted plants were grown. A split plot design with four replications was employed, with planting date as the whole plot factor and tomato cultivar and grafting combinations randomized in the subplots. Data loggers were installed to monitor temperature and light conditions inside the high tunnel. Tomato fruit were harvested twice a week, and marketable and unmarketable fruit number and weight were recorded. Plant growth characteristics were assessed after the final harvest for each planting date. Tomato fruit were also sampled during the growing season for quality assessment. Our preliminary results showed that early planting was more advantageous than late planting in high tunnel systems for spring tomato production in terms of plant health and tomato fruit yield. Following the tomato trial, a cowpea cover crop was planted in the high tunnels in mid-August 2018 to initiate the high tunnel nutrient management study for fall 2018. A PhD student was recruited in summer 2018 with the dissertation project focused on the integrated nutrient management research objective. A 30 ft × 80 ft tropical gutter connect screenhouse structure with insect netting was installed at the Florida A&M University Research and Extension Center in Quincy, FL in April 2018. The structure's recommended use includes commercial vegetable and high tunnel production. Upper and lower ridge (roof) is covered in greenhouse plastic, and a 2.5 ft × 80 ft vent runs the length of the upper and lower ridges. The ridge vent allows for passive roof top venting of hot air. Indoor shade overhead and drip irrigation has been installed to one-half of the structure growing area. Plantings of bok choy, mustard greens, and romaine lettuce were demonstrated for the spring field day. The leafy vegetables were grown on the irrigated half of the structure and a buckwheat cover crop was planted on the other half of the structure for crop rotation. Research objectives 4 and 5: Monitor and characterize plant pathogens infecting high priority organic high tunnel crops; Monitor population of arthropod pests and beneficials in high tunnel organic vegetable cropping systems. Plant samples were collected from the PSREU experimental high tunnels (Citra, FL) during the spring tomato trial and from the leafy green trial in the tropical gutter connect high tunnel (Quincy, FL). However, no pathogens of interest were observed. Biological organisms found were not plant pathogens, and the plant and fruit damages were attributed to insect problems. A preliminary biweekly sampling of the high tunnel organic tomato trial was conducted at PSREU from March 23 to July 27, 2018. Five yellow sticky cards and five 12-ounce yellow plastic bowls with soapy water were placed at alternating treatments per row. Traps were distributed on the morning of the sampling date and collected three days later. Tomatoes were also scouted for general pest pressure during the site visits. Due to the high sample volume, detailed summaries of samples detected by date are in preparation. From a pest perspective, thrips were the most numerous insect pest in the early season. Whiteflies predominated around May 21, 2018 and continued into the later date. Spider mites were more problematic in June and July. Objective 6: Develop cultural and biological alternatives for managing whiteflies and aphids. Sweetpotato whitefly and aphids are the major insect pests in horticultural crops in north Florida. Cultural control of these invasive insects is a sustainable management tool to mitigate the damage to organic vegetable crops in high tunnels. Attractive refuge plants such as marigold, basil, dill, and sweet alyssum were planted in the tropical screenhouse structure at the Florida A&M University Research and Extension Center (Quincy) in summer 2018. These plants are expected to enhance populations of beneficial insects that may reduce the numbers of whiteflies and aphids. Buckwheat cover crop was also planted in the screenhouse to reduce soil nematodes, increase fertility of the soil, and improve biological control in the system. Population densities of insects throughout the season were monitored by taking weekly samples of sticky traps, pitfall traps (for soil insects), and leaf counts. Data from the latter sampling methods continue to be processed and recorded. Preliminary results indicated that sweetpotato whiteflies, aphids, and thrips were the common insect pests in mustard and buckwheat plants. The beneficial insects or natural enemies of the insect pests collected were mainly big-eyed bugs and ladybeetles. In addition, attractive refuge flowering plants were also planted outside the screenhouse (marigold, milkweed, sunflower, commercial mix of flowering plants) to attract natural insect enemies and pollinators. Objective 7: Analyze on-farm economic viability of high tunnel organic vegetable production and identify the factors influencing high tunnel adoption among organic growers. We are currently developing the budget to estimate the costs of high tunnel systems including the construction and maintenance costs for different types of high tunnels. The established budget sheet will then be sent to collaborators in the project to collect detailed information. The key purpose is to estimate the total high tunnel costs during its lifespan and establish the relationship between costs of construction and the lifespan of high tunnels. \*\*PUBLICATIONS (not previously reported):\*\* 2017/09 TO 2018/08 1. Type: Conference Papers and Presentations Status: Other Year Published: 2018 Citation: Zhao, X. and C. Frey. 2018. Growing organic spinach: A research update. Southeast Regional Fruit & Vegetable Conference, Savannah, GA. 2. Type: Conference Papers and Presentations Status: Other Year Published: 2018 Citation: Zhao, X. and C. Frey. 2018.

Organic tomato production: A comparison between high tunnel and open field systems. Southeast Regional Fruit & Vegetable Conference, Savannah, GA. \*\* \*\*

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# Participatory Breeding and Testing Networks: a Maize Based Case Study for Organic Systems

<b>Accession No.</b>	1013016
<b>Project No.</b>	ILLU-875-628
<b>Agency</b>	NIFA ILLU\
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-27115
<b>Proposal No.</b>	2017-02413
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2021
<b>Grant Amount</b>	\$1,999,559
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Ugarte, C.; Andrade, JU, E.; Wander, MI, M.; Endres, A., BR.; Bohn, MA, O.; Formiga, AL, .; Davison, WI, .
<b>Performing Institution</b>	UNIVERSITY OF ILLINOIS, 2001 S. Lincoln Ave., URBANA, ILLINOIS 61801

## NON-TECHNICAL SUMMARY

This integrated multi-region project conducts advanced on-farm research to identify biophysical and social/legal factors influencing the performance of organic maize cultivars and dependent businesses. It exercises a participatory process that incorporates end-users into research and Extension activities done in concert with eOrganic to strengthen the organic seed supply and develop client-oriented breeding networks and business structures that deliver high-yielding, nutritious, N use efficient, weed-competitive genotypes adapted to organic systems. Our objectives are to: 1) Build capacity that supports a participatory testing and breeding program; 2) Conduct a maize-based case study to explore on-farm factors influencing crop fitness and grain quality; and 3) Identify and communicate how organizational structures, sharing, and intellectual property agreements can promote client-oriented breeding programs to improve our organic seed supply. Important inputs include promising cultivars, experienced advisors, and significant farmer input. Proposed activities include on-farm research on corn hybrids and synthetics, manipulative experiments to assess the effects of soil health and plant-soil interactions on crop fitness and grain quality, study of business models to address the intellectual property and germplasm sharing issues that challenge open source seed networks, and the development of outreach and education materials to increase the success of publically supported breeding efforts and associated businesses. Key outcomes and outputs include regionally adapted maize cultivars, eOrganic articles, standardized testing and phenotyping protocols, and expert-recommended sharing agreements and business structures.

## OBJECTIVES

The overarching goal of this project is to strengthen local and regional organic food systems by increasing our ability to use organic management, on-farm selection and testing, and participatory networks to improve organic germplasm (in this case maize) to satisfy end-user's preferences and spawn new markets. The specific project objectives are to: 1) Build capacity that supports a participatory testing and breeding program for organic agriculture; 2) Conduct a maize-based case study to explore on-farm factors influencing crop fitness and grain quality; and 3) Identify and communicate how organizational structures, sharing, and intellectual property agreements can promote client-oriented breeding programs to improve our organic seed supply and increase opportunities for production, supply, and distribution of organic products.

## APPROACH

Objective 1: Build capacity that supports a participatory testing and breeding program: \1\ This starts with the determination of priority traits and the selection of a core set of hybrids for testing in on-farm studies; \2\ Develop protocols and instruction manuals for strip trials, management and data collection in on-farm studies; \3\ Organize one-on-one visits to collaborating farmers to discuss experimental design and collect information on history of management; \4\ Carry out field days to review cultivar performance and share results and experiences from the testing network; and \5\ Carry out phenotypic evaluation of newly crossed genotypes using different treatments representing contrasts of N availability, planting density, and seeding dates. Objective 2: Conduct a maize-based case study to explore on-farm factors influencing crop fitness and grain quality: \1\ Conduct seed multiplication of selected genetic material based on N use efficiency, yield, and feed quality (protein, methionine, lysine), and agronomic performance with diverse root morphologies, food processing characteristics, and nutritional value; \2\ Conduct controlled, replicated, and on-farm strip trials to: (i) Estimate accurately basic genetic parameters (i.e., genetic and G×E×M interaction variance components, general and specific combining abilities, heritability, gene action) for traits determining performance of corn in organic systems and to use these for designing efficient breeding strategies; and (ii) Identify sources of favorable alleles to improve adaptation and performance in organic systems; \3\ Evaluation of soil quality and soil management conditions for fields used for on-farm trials; \4\ Evaluate plant-soil relationships in replicated on-farm field studies; \5\ Carry out grain quality evaluations as influenced by management; and \6\ Develop data sharing mechanisms. Objective 3: Identify and communicate how organizational structures, sharing, and intellectual property agreements can promote client-oriented breeding programs to improve our organic seed supply. \1\ This begins with the formalization of the Advisory Board and the identification of constraints and opportunities of locally produced grains; \2\ Organize a writing retreat with the Advisory Board members; \3\ Review models for networks and partnerships; \4\ Input received from the Advisory Board will be used as criteria for project evaluation; \5\ Design and implement a mid-project survey that evaluates the projects' performance based on perceived strengths and weaknesses of the processes and procedures; \5\ Carry out focus groups and follow-up semi-structured interviews regarding data sharing and farmer engagement; \6\ Organize a webinar on network structure and information sharing recommendations; and \7\ Organize a workshop at the MOSES Organic Farming Conference and conduct a final project evaluation tailored for farmers, researchers, and end-users to assess project results and satisfaction with outcomes. \*\*Progress\*\* 09/01/17 to 08/31/22 \*\*Outputs\*\* Target Audience: The target audience for this project included groups of farmers, seed producers, researchers, educators, public and private plant breeders, food scientists and processors, and end-users of organic grain products. Actors involved or interested in this project were generally eager to support a participatory testing network throughout the project and will continue to engage to inform future crop breeding efforts to meet the needs and wants of end-users of organic germplasm. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? For the duration of the project, we worked with four graduate students (one MS, and three PhD), a visiting scientist, and two postdocs who were instrumental in coordinating on-farm work, laboratory testing, and data management. All students have contributed to the communication of our research findings. Following the mission of the University of Illinois, Ugarte, Wander, Bohn, and Andrade hosted a total of thirty undergraduate students from the University of Illinois and University of Illinois partners \Zamorano University (Honduras), Federal University of Goiás (Brazil), and Zhejiang University (China)\. We also established the Illinois Organic Internship for undergraduate students from under-represented groups interested in research in organic and sustainable cropping systems. Throughout the project undergraduate students were involved in all project activities and worked closely with graduate students. Several of them have continued on in graduate programs in diverse fields including sustainable agriculture, ecology, and food science and human nutrition. How have the results been disseminated to communities of interest? A variety of methods were used to disseminate project results. We curated outreach material that has been delivered through virtual venues including the project's website, the project's Instagram account, the eOrganic youtube channel, Zoom meetings and in person through the Illinois Agronomy Day. Findings were also presented at scientific meetings including the Agronomy-Crop-Soil Science Society of America International Annual Meetings, the Corn Breeders School, the Cereals and the Grain Association Annual Meeting. Finally, results have been submitted for peer-review; two articles are already published with additional upcoming publications that will be published resulting from graduate student MS thesis and dissertations. 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 integrated Multi-Regional Project conducted advanced on-farm research to identify biophysical and social/legal factors influencing the performance of organic maize cultivars and dependent businesses. It exercised a participatory process that incorporated end-users into research and Extension activities done in concert with eOrganic to strengthen the organic seed supply and develop client-oriented breeding networks and business structures that deliver high-yielding, nutritious, N use efficient, weed-competitive genotypes adapted to organic systems. At on-farm locations, we tested cultivars developed by four

breeding programs that had distinctly different breeding objectives. Results revealed a wide range in agronomic performance resulting from significant variability in the management practices used by participating farmers. We developed a typology of management that helped in capturing some of the variability that is introduced by on-farm management practices and farmer's philosophies of management. This contributed to a better understanding of management as a selective pressure across geographically distant on-farm sites. Using farm typology, we can identify the characteristics or traits that are important to study under controlled conditions and how management is influencing soil health which is directly related to crop performance. Work under controlled experiments helped us to understand maize root phenotypic responses to different fertility management regimes. We quantified the root angle and root complexity based on measurements of fractal dimensions of branching points of coarse roots. Root angle gives us an idea of the depth and direction of root exploration for nutrient acquisition. Overall, we found a negative relationship between root complexity and crop performance. While we may think that with higher root complexity there is more root exploration and more N uptake, there is also a higher carbon investment in the root system that reduced yield. We found a positive relationship between root angle and yield, suggesting that steeper root systems are positively related with yield in our region. This is likely the case as roots were able to exploit a larger soil volume and uptake water during critical plant growth stages. When we evaluated fine root traits, which are critical for nutrient and water uptake, we found genotypic differences. The hybrids that showed greater investment in fine roots traits including root length density and specific root area, were those hybrids with lower root complexity. Despite the establishment of fertility management regimes, our systems were characterized by optimal N supply. Therefore, our results, highlight the need to monitor environmental stressors beyond soil fertility in order to better understand agronomic responses in this region. Companion work that explored the influence of the seed loophole on the quantity and quality of maize seed in the US found that about 75% of US organic corn is grown from organically produced seed. Participants in our network suggest the risks that are associated with the production of organic seed present a larger challenge for investment than the seed loophole. Through a series of interactions with actors involved in the seed industry we identified a variety of traits that define seed quality, and determined how the traits of interest vary depending on who uses the seed and its purposes. In addition to traits that are related to productivity, agronomic success and grain quality related to potential end-use that are widely reported by seed retailers, we identified gaps where there are needs for additional information. This includes seed characteristics that are related to environmental performance or public health. In many cases, the organic label is used by consumers as a proxy for environmental performance. Other traits like harvest index, functions in the rhizosphere, and nutrient use efficiency that are of interest to farmers and consumers, are rarely reported. A broadened list of traits of interest should inform future maize selection efforts. \*\*Publications\*\* - Type: Journal Articles Status: Published Year Published: 2022 Citation: Endres, A.B., M.O. Bohn, J.E. Andrade, W.A. Goldstein, E.E. Marriott, A.K. Formiga, C.M. Ugarte, and M.M. Wander. 2022. Influence of the seed loophole and bottleneck on quantity and quality of organic maize seed in the U.S. *Frontiers in Agronomy*. doi: 10.3389/fagro.2022.763974 - Type: Theses/Dissertations Status: Other Year Published: 2022 Citation: Mujjabi, C. 2022. The use of participatory breeding and testing networks in maize varietal development for organic systems. (M.S. Thesis. University of Illinois at Urbana-Champaign). - Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: Wander, M.M., Lammerts van Bueren, E., Nawaz, S., Klassen, S., and Schrager, B. 2022. Systems based research networks. Panel Discussion at the 11th Organic Seed Alliance Annual Conference. - Type: Journal Articles Status: Other Year Published: 2023 Citation: A collection of papers addressing how transdisciplinary research networks can select for food and farming systems traits that provide social and environmental goods related to health, fairness and care will appear in 2023 at the Journal of Agriculture, Food Systems, and Community Development (JAFSCD). \*\*Progress\*\* 09/01/20 to 08/31/21 \*\*Outputs\*\* Target Audience: The target audience for this project includes groups of farmers, seed producers, researchers, educators, public and private plant breeders, food scientists and processors, and end-users of organic products interested in supporting a participatory testing network that will inform future breeding efforts to meet the needs and wants of end-users of organic germplasm. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? In the last year, the project has involved four graduate students and a visiting scientist. They have continued to be instrumental in coordinating on-farm work, laboratory testing, and data management. Following the mission of the University of Illinois, we continue to provide opportunities for students at Illinois and at University of Illinois partners; Ugarte, Wander, and Bohn hosted six undergraduate students from the University of Illinois and one undergraduate student from Zamorano University (Honduras). We established the "Illinois Organic Internship" for undergraduate students from under-represented groups interested in organic and sustainable cropping systems research. Three undergraduate students were recruited for the Illinois Organic Internship in the Summer 2021. Similar to previous years, undergraduate students were involved in all project activities and worked closely with graduate students. How have the results been disseminated to communities of interest? The primary form for disseminating results this year has been through virtual venues, including the project's website and Instagram account, the eOrganic Youtube channel, Zoom meetings, and in-person through the Illinois Agronomy Day. What do you plan to do

during the next reporting period to accomplish the goals? We are organizing a roundtable discussion to be part of the Organic Seed Growers Conference (Feb 4-11, 2022) and an online retreat to discuss how do we facilitate and connect breeders with others in the research and development pipeline and engage the organic/regenerative community in the development of ecologically and socially resilient systems. We will organize a final year of trials at the University of Illinois. We will leverage the controlled conditions that reduce the variability due to inherent soil properties and management and use the three-year and four-year rotation long-term study that has been established for purposes of organic cropping systems research. Conduct molecular work that tests the presence and abundance of functional groups associated with plant growth promotion, yield, and grain quality characteristics. We are working on peer-review publications and technical notes for result dissemination to the scientific community and the groups of stakeholders that are part of the participatory and testing networks.

**\*\*Impacts\*\*** What was accomplished under these goals? This calendar year we focused on maintaining the participatory and testing network established in the previous years. Results revealed differences in agronomic characteristics of germplasm that was bred in fields under organic management as compared with the material developed at the University of Illinois under more controlled conditions in terms of nutrients and weed competition. The germplasm developed at the University of Illinois was derived from ex PVP sources and its yield potential is comparable to commercially available checks. Soil health assessment revealed the need to understand other factors beyond N fertility to improve recommendations and management that optimized yield in organic systems. Hybrids from different breeding backgrounds responded differently to conditions of organic matter management. For example, hybrids developed under organic management background seem to have greater root complexity and lower fine root. Observations in regards to grain quality characteristics as influenced by management revealed that planting location, nitrogen treatments, and genotype are stronger factors influencing quality than weed pressure. As expected, increased nitrogen resulted in greater protein and oil content, whereas starch content decreased. Hybrids of interest presented a broad nutrient composition, especially in carotenoid, Zn, Fe, Mn, and methionine content. Kernel color was moderately associated with total carotenoid content but to a lesser extent to single carotenoids. Multivariate statistical analysis revealed differences in genotypes from different breeding programs. This analysis also showed that protein, oil, amino acids, and carotenoid content were inversely proportional to starch and fiber content. We identified traits of interest to guide future maize breeding programs for organic grain cropping systems. We also identified biological and market-based strategies to improve seed production of hybrid corn. **\*\*Publications\*\*** - Type: Journal Articles Status: Under Review Year Published: 2021 Citation: Endres, A.B., M.M. Wander, J.E. Andrade Laborde, M.O. Bohn, A.K. Formiga, W. Goldstein, E. Marriott and C.M. Ugarte. 2021. Influence of the seed loophole and bottleneck on quantity and quality of organic maize seed in the U.S. (Under Review). - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Ghimire, B., Mujjabi, C., Ugarte, C. M., Bohn, M. and Wander, M. 2021. Influence of Genotype and Management on Carbon and Nitrogen Mineralization Dynamics in Organic Maize Production \Abstract\. ASA, CSSA, SSSA International Annual Meeting, Salt Lake City, UT. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Bohn, M. 2021. Organic Corn Breeding. Illinois Agronomy Day. University of Illinois at Urbana-Champaign. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Ugarte, C.M., Bohn, M., Wander, M., Andrade, J., Endres, B., Goldstein, W., Mujjabi, C., Ghimire, B., Gulkirpik, E., Toc, M. and Nunez, M. 2021. Participatory Breeding and Testing Networks: A Maize Based Case Study for Organic Systems \Abstract\. ASA, CSSA, SSSA International Annual Meeting, Salt Lake City, UT. <https://scisoc.confex.com/scisoc/2021am/meetingapp.cgi/Paper/138954>. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Mujjabi, C., Ghimire, B., Ugarte, C.M., Wander, M., Goldstein, W. and Bohn, M. 2021. Evaluation of the Usefulness of Exvpv Maize Germplasm in Hybrid Development for Organic Maize Systems Using Participatory Variety Testing \Abstract\. ASA, CSSA, SSSA International Annual Meeting, Salt Lake City, UT. <https://scisoc.confex.com/scisoc/2021am/meetingapp.cgi/Paper/139199>. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Ugarte, C.M. 2021. Organic Grain Farming Research at Illinois. Illinois Agronomy Day. University of Illinois at Urbana-Champaign. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Toc M., Gulkirpik E. and Andrade Laborde J. 2021. Grain Quality Attributes of New Organic Corn Hybrids Grown at Three Midwestern U.S. States \Poster Session\. Institute of Food Technologists (IFT) F.I.R.S.T. Annual Event. Online. [https://ift21.mapyourshow.com/8\\_0/sessions/session-details.cfm?ScheduleID=296](https://ift21.mapyourshow.com/8_0/sessions/session-details.cfm?ScheduleID=296). - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Toc M., Gulkirpik E. and Andrade Laborde J. 2021. A Machine Learning Model to Predict Carotenoid Content in Corn Using Reflectance Colorimetry \Poster Session\. Institute of Food Technologists (IFT) F.I.R.S.T. Annual Event. Online. [https://ift21.mapyourshow.com/8\\_0/sessions/session-details.cfm?ScheduleID=288](https://ift21.mapyourshow.com/8_0/sessions/session-details.cfm?ScheduleID=288).

## PROGRESS

2017/09 TO 2018/08 Target Audience: The target audience for this project includes groups of farmers, researchers, educators, public and private plant breeders, food scientists and processors, and end-users of organic products interested in supporting a participatory testing network that will inform future breeding efforts to meet the needs and wants of end-users of organic germplasm. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? This project has provided training opportunities for undergraduate students from institutions that partner with the University of Illinois through the Office of International Programs in the College of Agricultural, Consumer and Environmental Sciences. One student from Zamorano University (Honduras) and one student from Zhejiang University (China) have been involved in soil health evaluations and corn breeding research. 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? Execution of activities for this project is on target. PIs are reaching out to more farmers that are interested in engaging in the participatory network.

2018/09 TO 2019/08 Target Audience: The target audience for this project includes groups of farmers, seed producers, researchers, educators, public and private plant breeders, food scientists and processors, and end-users of organic products interested in supporting a participatory testing network that will inform future breeding efforts to meet the needs and wants of end-users of organic germplasm. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? To date, the project has involved four graduate students who have been instrumental in coordinating on-farm work, laboratory testing, and data management. This project has also provided training opportunities for undergraduate students within the University of Illinois and University of Illinois partners. A total of 11 undergraduate students contributed to the project and were trained in various field and laboratory methods related to corn breeding, soil quality assessment, field plot maintenance, and grain quality evaluations. A student from Zamorano University (Honduras) who was part of the project in 2018 extended his post-graduation internship and has been involved in coordinating field activities during the 2019 growing season. In the Spring of 2019 an undergraduate student from Zamorano University completed a senior internship with the food science group and contributed to grain quality analysis using NIR-based methods. In the summer of 2019, a new student from Zhejiang University (China) contributed to protocol development for enzyme assays in the soils group. How have the results been disseminated to communities of interest? Preliminary results have been disseminated at farmer conferences, field days, and online publications. Direct links to materials presented reside in our project website. What do you plan to do during the next reporting period to accomplish the goals? Execution of activities for this project is on target. We continue to recruit farmers, seed producers, and processors that are interested in engaging in the participatory network.

2019/09 TO 2020/08 Target Audience: The target audience for this project includes groups of farmers, seed producers, researchers, educators, public and private plant breeders, food scientists and processors, and end-users of organic products interested in supporting a participatory testing network that will inform future breeding efforts to meet the needs and wants of end-users of organic germplasm. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? In the last year, the project has involved four graduate students who have continued to be instrumental in coordinating on-farm work, laboratory testing, and data management. Following the mission of the University of Illinois, we continue to provide opportunities for students at Illinois and at University of Illinois partners. While limited due to challenges associated with COVID-19, Ugarte and Wander hosted three undergraduate students from the University of Illinois, and one undergraduate student from the Federal University of Goiás (Brazil). Bohn hosted two undergraduate students from Illinois. Andrade hosted two undergraduate students from Illinois and a visiting scholar from Honduras. Students contributed to the project and were trained in various laboratory and field techniques related to corn breeding, biological methods for soil quality assessment, and grain quality evaluations. A former student from Zamorano University (Honduras) who was part of the project since 2018, extended his appointment and has been involved in coordinating field activities and supporting the work of graduate students in the breeding and soil evaluation components of the project. By leveraging activities in this project, Ugarte, Bohn, and Wander, applied for additional support from the University of Illinois Student Sustainability Committee to fund a student training/internship program of underrepresented students in the 2021 and 2022 academic years. How have the results been disseminated to communities of interest? The primary form for disseminating results this year has been through virtual venues including the eOrganic youtube channel, the project's website, and the project's Instagram account. What do you plan to do during the next reporting period to accomplish the goals? While COVID-19 has limited our ability to conduct laboratory research, the team has been able to maintain a reduced staff to stay on target with scheduled project activities. We continue to recruit stakeholders interested in the educational network and welcome new participation in the testing network.

2020/09 TO 2021/08 Target Audience: The target audience for this project includes groups of farmers, seed producers, researchers, educators, public and private plant breeders, food scientists and processors, and end-users of organic products interested in supporting a participatory testing network that will inform future breeding efforts to meet the needs and wants of end-users of organic germplasm. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? In the last year, the project has involved four graduate students and a visiting scientist. They have continued to be instrumental in coordinating on-farm work, laboratory testing, and data management. Following the mission of the University of Illinois, we continue to provide opportunities for students at Illinois and at University of Illinois partners; Ugarte, Wander, and Bohn hosted six undergraduate students from the University of Illinois and one undergraduate student from Zamorano University (Honduras). We established the "Illinois Organic Internship" for undergraduate students from under-represented groups interested in organic and sustainable cropping systems research. Three undergraduate students were recruited for the Illinois Organic Internship in the Summer 2021. Similar to previous years, undergraduate students were involved in all project activities and worked closely with graduate students. How have the results been disseminated to communities of interest? The primary form for disseminating results this year has been through virtual venues, including the project's website and Instagram account, the eOrganic Youtube channel, Zoom meetings, and in-person through the Illinois Agronomy Day. What do you plan to do during the next reporting period to accomplish the goals? We are organizing a roundtable discussion to be part of the Organic Seed Growers Conference (Feb 4-11, 2022) and an online retreat to discuss how do we facilitate and connect breeders with others in the research and development pipeline and engage the organic/regenerative community in the development of ecologically and socially resilient systems. We will organize a final year of trials at the University of Illinois. We will leverage the controlled conditions that reduce the variability due to inherent soil properties and management and use the three-year and four-year rotation long-term study that has been established for purposes of organic cropping systems research. Conduct molecular work that tests the presence and abundance of functional groups associated with plant growth promotion, yield, and grain quality characteristics. We are working on peer-review publications and technical notes for result dissemination to the scientific community and the groups of stakeholders that are part of the participatory and testing networks.

## IMPACT

2017/09 TO 2018/08 What was accomplished under these goals? Our integrated Multi-Regional Project conducts advanced on-farm research to identify biophysical and social/legal factors influencing the performance of organic maize cultivars and dependent businesses. It exercises a participatory process that incorporates end-users into research and Extension activities done in concert with eOrganic to strengthen the organic seed supply and develop client-oriented breeding networks and business structures that deliver high-yielding, nutritious, nitrogen use efficient, weed-competitive genotypes adapted to organic systems. Efforts in Year One focused on: 1) establishing protocols for testing and determining suitable mechanisms to support long-lasting participatory testing networks; 2) designing, implementing, and collecting on-farm data that leads us to identify the factors influencing crop fitness and performance in organic farming systems; and 3) to understand the multiple ways in which the plant breeding landscape has been changing and how plant varieties are owned and protected with intellectual property rights. This is important as plant breeders and researchers will require new ways of approaching plant breeding to serve the needs of participatory networks.

2018/09 TO 2019/08 What was accomplished under these goals? Our integrated Multi-Regional Project conducts advanced on-farm research to identify biophysical and social/legal factors influencing the performance of organic maize cultivars and dependent businesses. It exercises a participatory process that incorporates end-users into research and Extension activities done in concert with eOrganic to strengthen the organic seed supply and develop client-oriented breeding networks and business structures that deliver high-yielding, nutritious, N use efficient, weed-competitive genotypes adapted to organic systems. Efforts in Year 2 have focused on replicating work started in Year 1. More specifically we continue: 1) Collecting on-farm data that leads us to identify the factors influencing crop fitness and performance in organic farming systems; and 2) Understanding the attributes of seed and grain quality that is of interest to farmers, seed producers, processors and end-users.

**\*\*PUBLICATIONS (not previously reported):\*\*** 2018/09 TO 2019/08 1. Type: Other Status: Published Year Published: 2018 Citation: Luby, C., A.B. Endres, M. Wander and C. Ugarte. 2018. A primer on plant breeding and intellectual property rights in organic seed systems. The eXtension Foundation. Available online at: . 2. Type: Conference Papers and Presentations Status: Other Year Published: 2019 Citation: Bohn, M., W. Goldstein and W. Davison. 2019. Corn breeding for organic markets. The eXtension Foundation. Webinar available at: . 3. Type: Conference Papers and Presentations Status: Other Year Published: 2019 Citation: Ugarte, C., M. Bohn,

M. Wander, J. Andrade, W. Goldstein, C. Mujjabi, B. Ghimire and E. Gulkirpik. 2019. Participatory breeding and testing networks: A maize-based case study for organic systems. The Land Connection Organic Grain Conference. Champaign, Illinois. 4. Type: Conference Papers and Presentations Status: Other Year Published: 2019 Citation: Mujjabi, C., B. Ghimire, E. Gulkirpik, M. Núñez, C. Ugarte, M. Bohn, M. Wander and J. Andrade. 2019. Participatory breeding and testing networks: Corn variety development and selection for high nitrogen-use efficiency, weed pressure tolerance and high grain quality for organic systems. 55th Annual Illinois Corn Breeders School. Champaign, Illinois.

2019/09 TO 2020/08 What was accomplished under these goals? Participation in the testing network, as well as in an educational network, has expanded over the first three years of the project. Efforts on the testing network have been focused on improving the statistical power of our trials by increasing the number of site-year observations. Preliminary results revealed differences in agronomic characteristics of germplasm that was bred in fields under organic management as compared with the material developed at the University of Illinois under more controlled conditions in terms of nutrients and weed competition. Soil health assessment revealed the need to understand other factors beyond N fertility to improve yields in organic systems. Observations in regards to grain quality characteristics as influenced by management revealed that planting location, nitrogen treatments, and genotype are stronger factors influencing quality than weed pressure. As expected, increased nitrogen resulted in greater protein and oil content, whereas starch content decreased. Hybrids of interest presented a broad nutrient composition, especially in carotenoid, Zn, Fe, Mn, and methionine content. Kernel color was moderately associated with total carotenoid content but to a lesser extent to single carotenoids. Multivariate statistical analysis revealed differences in genotypes from different breeding programs. This analysis also showed that protein, oil, amino acids, and carotenoid content were inversely proportional to starch and fiber content. As an outcome from the workshop held at the 2019 ASTA Meeting, the team identified biological and market-based strategies to improve seed production of hybrid corn. An upcoming manuscript will fully develop findings from the workshop and additional input from our advisory board. \*\*PUBLICATIONS (not previously reported):\*\* 2019/09 TO 2020/08 1. Type: Other Status: Published Year Published: 2020 Citation: Corn and Soil Health Team. 2020. Ears to the Ground Virtual Field Day Series. Part 1: Soil Nitrogen Tests Overview Available online at: 121 views through 09/08/2020. 2. Type: Other Status: Published Year Published: 2020 Citation: Corn and Soil Health Team. 2020. Ears to the Ground Virtual Field Day Series. Part 2: ISNT and PSNT Soil Nitrogen Tests. Available online at: <https://www.youtube.com/watch?v=JXx9xU7mfAl> 94 views through 09/08/2020. 3. Type: Other Status: Published Year Published: 2020 Citation: Corn and Soil Health Team. 2020. Ears to the Ground Virtual Field Day Series. Part 3: Solvita and SLAN Soil Nitrogen Tests. Available online at: 108 views through 09/08/2020. 4. Type: Other Status: Published Year Published: 2020 Citation: Corn and Soil Health Team. 2020. Ears to the Ground Virtual Field Day Series. Part 4: Soil N Tests on On-Farm Studies. Available online at: 96 views through 09/08/2020. 5. Type: Conference Papers and Presentations Status: Accepted Year Published: 2020 Citation: Goldstein, W., White, J., Mujjabi, C., Gulkirpik, E., Toc, M., Bohn, M., Andrade, J.E., Ugarte, C., Nunez, M., Karnes, J., Lotfi, A., Kingsley, K., Travis, M., Wander, M., Jaradat, A., Mohr, S. and Organic Farmers. 2020. Breeding and Testing Nitrogen Efficient/Fixing Corn with High Methionine and Carotenoid Contents for Organic Farmers. Poster presented at: MOSES Organic Farming Conference; 2020 Feb 27-29; LaCrosse, WI. 6. Type: Conference Papers and Presentations Status: Accepted Year Published: 2020 Citation: Mujjabi, C. and Bohn, M. 2020. Participatory Plant Breeding: Effect of Agronomic Management Intensity on Below-Ground and Above-Ground Corn Traits Under Organic Systems. Poster presented at: 5th Biennial Plant Breeding Symposium, February 2020; North Carolina State University, Raleigh, NC. 7. Type: Conference Papers and Presentations Status: Accepted Year Published: 2019 Citation: Mujjabi, C., Ghimire, B., Gulkirpik, E., Núñez, M., Ugarte, C., Bohn, M., Wander, M. and Andrade, J. 2019. Participatory Breeding and Testing Networks: Corn Variety Development and Selection for High Nitrogen-Use Efficiency, Weed Pressure Tolerance and High Grain Quality for Organic Systems. Poster presented at: 2019 Illinois Corn Breeders School, March 2019; Champaign, IL. 8. Type: Conference Papers and Presentations Status: Accepted Year Published: 2019 Citation: Gulkirpik, E. Toc, M. Bogran, G. Katrakis, C. Ugarte, C.M. and Andrade, J.E. 2019. Effect of Nitrogen Levels on the Nutrient Quality of Corn Under Organic Management. Poster Presented at AACC International, November, 2019; Denver, CO.

2020/09 TO 2021/08 What was accomplished under these goals? This calendar year we focused on maintaining the participatory and testing network established in the previous years. Results revealed differences in agronomic characteristics of germplasm that was bred in fields under organic management as compared with the material developed at the University of Illinois under more controlled conditions in terms of nutrients and weed competition. The germplasm developed at the University of Illinois was derived from exPVP sources and its yield potential is comparable to commercially available checks. Soil health assessment revealed the need to understand other factors beyond N fertility to improve recommendations and management that optimized yield in

organic systems. Hybrids from different breeding backgrounds responded differently to conditions of organic matter management. For example, hybrids developed under organic management background seem to have greater root complexity and lower fine root. Observations in regards to grain quality characteristics as influenced by management revealed that planting location, nitrogen treatments, and genotype are stronger factors influencing quality than weed pressure. As expected, increased nitrogen resulted in greater protein and oil content, whereas starch content decreased. Hybrids of interest presented a broad nutrient composition, especially in carotenoid, Zn, Fe, Mn, and methionine content. Kernel color was moderately associated with total carotenoid content but to a lesser extent to single carotenoids. Multivariate statistical analysis revealed differences in genotypes from different breeding programs. This analysis also showed that protein, oil, amino acids, and carotenoid content were inversely proportional to starch and fiber content. We identified traits of interest to guide future maize breeding programs for organic grain cropping systems. We also identified biological and market-based strategies to improve seed production of hybrid corn. \*\*PUBLICATIONS (not previously reported):\*\* 2020/09 TO 2021/08 1. Type: Journal Articles Status: Under Review Year Published: 2021 Citation: Endres, A.B., M.M. Wander, J.E. Andrade Laborde, M.O. Bohn, A.K. Formiga, W. Goldstein, E. Marriott and C.M. Ugarte. 2021. Influence of the seed loophole and bottleneck on quantity and quality of organic maize seed in the U.S. (Under Review). 2. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Ghimire, B., Mujjabi, C., Ugarte, C. M., Bohn, M. and Wander, M. 2021. Influence of Genotype and Management on Carbon and Nitrogen Mineralization Dynamics in Organic Maize Production \Abstract\ ASA, CSSA, SSSA International Annual Meeting, Salt Lake City, UT. 3. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Bohn, M. 2021. Organic Corn Breeding. Illinois Agronomy Day. University of Illinois at Urbana-Champaign. 4. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Ugarte, C.M., Bohn, M., Wander, M., Andrade, J., Endres, B., Goldstein, W., Mujjabi, C., Ghimire, B., Gulkirpik, E., Toc, M. and Nunez, M. 2021. Participatory Breeding and Testing Networks: A Maize Based Case Study for Organic Systems \Abstract\ ASA, CSSA, SSSA International Annual Meeting, Salt Lake City, UT. <https://scisoc.confex.com/scisoc/2021am/meetingapp.cgi/Paper/138954>. 5. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Mujjabi, C., Ghimire, B., Ugarte, C.M., Wander, M., Goldstein, W. and Bohn, M. 2021. Evaluation of the Usefulness of Expvp Maize Germplasm in Hybrid Development for Organic Maize Systems Using Participatory Variety Testing \Abstract\ ASA, CSSA, SSSA International Annual Meeting, Salt Lake City, UT. <https://scisoc.confex.com/scisoc/2021am/meetingapp.cgi/Paper/139199>. 6. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Ugarte, C.M. 2021. Organic Grain Farming Research at Illinois. Illinois Agronomy Day. University of Illinois at Urbana-Champaign. 7. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Toc M., Gulkirpik E. and Andrade Laborde J. 2021. Grain Quality Attributes of New Organic Corn Hybrids Grown at Three Midwestern U.S. States \Poster Session\ Institute of Food Technologists (IFT) F.I.R.S.T. Annual Event. Online. <https://ift21.mapyourshow.com/80/sessions/session-details.cfm?ScheduleID=296>. 8. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Toc M., Gulkirpik E. and Andrade Laborde J. 2021. A Machine Learning Model to Predict Carotenoid Content in Corn Using Reflectance Colorimetry \Poster Session\ Institute of Food Technologists (IFT) F.I.R.S.T. Annual Event. Online. <https://ift21.mapyourshow.com/80/sessions/session-details.cfm?ScheduleID=288>.

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# Accelerating Corn Elite Selections (aces) Organic Breeding Program: Novel Strategies to Develop Field & Sweet Corn for Organic Producers

<b>Accession No.</b>	1013072
<b>Project No.</b>	IOW05510
<b>Agency</b>	NIFA IOWA
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26811
<b>Proposal No.</b>	2017-02493
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2021
<b>Grant Amount</b>	\$1,000,000
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Lubberstedt, T.; Tracy, W, F.; Scott, P, .; Delate, K.
<b>Performing Institution</b>	IOWA STATE UNIVERSITY, 2229 Lincoln Way, AMES, IOWA 50011

## NON-TECHNICAL SUMMARY

Our project advances goals one and eight of the USDA OREI Program: 1. Facilitating the development of organic agriculture production, breeding, and processing methods. 8. Developing new and improved seed varieties that are particularly suited for organic agriculture. Moreover, the project addresses priority area (4) for FY2017: Strengthen organic crop seed systems, including seed and transplant production and protection, and plant breeding for organic production, with an emphasis on publicly available releases. Goals include: disease, weed, and pest resistance, stress tolerance, nutrient efficiency, performance in soil-improving and climate-friendly systems such as organic no-till, quality and yield improvement, and genetic mechanisms to prevent inadvertent introduction of GMO traits through cross-pollination. Our project will develop close-to-variety (elite) organic sweet and field corn genotypes carrying a genetic mechanism for spontaneous haploid genome doubling (SHGD), as well as GCI, which will enable more rapid development of superior organic varieties protected against transgene contamination. These materials will be made available to organic breeders, seed producers, and farmers. Both genetic mechanisms together will allow implementation of DH technology in organic corn breeding. The DH technology to be implemented will not require application of chemicals (e.g., colchicine), and it will be combined with gametophytic cross-incompatibility (GCI) to exclude pollen from transgenic field corn - an urgent problem for organic farmers today. Cooperative research will flourish through a network of organic farmers, government agency staff (NRCS, ARS), organic seed companies, and university researchers, based on on-station and on-farm that will include plant breeding activities and organic seed production. Extension activities, including field days, conferences, workshops, and state advisory teams, will facilitate variety evaluation, build plant-breeding capacity among organic farmers, and advance the development of superior genetic material. Organic seed companies will be full partners by participating on advisory teams, evaluating elite genotypes, and assisting in disseminating project results. A Certificate program in Organic Plant Breeding will be available to graduate students, producers, and other interested persons/parties. Classes will be offered online to allow participation around the globe.

## OBJECTIVES

The overall goal of the project is to substantially increase the productivity of organic field and sweet corn production within organic crop rotations, by improving the efficiency of breeding through doubled haploid (DH) technology and traditional breeding methods, focused on early plant vigor and competitiveness factors. Another goal is to develop a Certificate program in Organic Plant Breeding, which can be accessed online in the U.S. and internationally. Objectives...1. Develop novel organic field corn and sweet corn genotypes for the commercialization pipeline that utilize more efficient methods of breeding (e.g., organic-compliant Doubled Haploid technology)2. Select and test on-farm genotypes that meet the critical needs of organic producers, including high yields, competitiveness with weeds, and compatibility with cover crops and ability to exclude GMO pollen3. Practice technology transfer through a network with organic farmers and organic seed companies that allows for plant-breeding, selection, evaluation and seed processing training and skill development4. Develop a graduate Certificate program in Organic Plant Breeding

## APPROACH

Objective 1. Novel organic field & sweet corn genotypes for commercialization pipeline utilizing DH technology & GMO incompatibility. This project includes two thrusts for developing high performing organic field and sweet corn materials, which contain the two genetic mechanisms of spontaneous haploid genome doubling (SHGD) and gametophytic cross-incompatibility (GCI). In the first thrust, field and sweet corn DH lines already containing SHGD will be evaluated under organic field conditions, and the best lines converted for GCI. In the second thrust, a donor genotype carrying both SHGD and GCI will be developed prior to project start, elite organic sweet and field corn materials will be converted for both traits, and subsequently evaluated for testcross (TC) performance under organic conditions. In both of these thrusts, we will develop several families of lines that perform well in hybrid combinations. This will be accomplished by starting with sweet and field corn breeding germplasm with well-characterized combining ability. This will allow us to produce competitive hybrids using our new inbreds as parents. Finally, advanced organic hybrids will be evaluated under organic conditions, and educational materials and activities developed to enhance producer knowledge and dissemination of project outputs. Objective 2: Select and test on-farm genotypes that meet the critical needs of organic producers. In this component, on-farm trials in Years 2-4 will be established to conduct extensive organic evaluation of 1) the most promising field and sweet corn hybrids made from experimental inbreds developed at ISU and UW, and from the OREI corn quality breeding project; and 2) testcrosses that carry the SHGD/GCI background, when available for evaluation. Their performance in the presence of cover crops will constitute a main focus, along with their competitiveness with weeds. Once advanced lines are developed on-station, seed will be distributed to cooperating farmer-cooperators for on-farm testing and evaluation. All farms are certified organic with a history of organic corn production, and an Organic System Plan that is based on a soil-building crop rotation. Ideally, the corn crop will follow a legume and soil samples in the Fall prior to planting will determine the amount of manure application in the spring. Because the trials will be based on 'farmer reality,' farmers may adapt their management to match their farm, but manure applications will be monitored to supply no more than 150 lb N/acre to evaluate corn production across equivalent soil fertility conditions. Breeders will provide sufficient seed in order to plant three replications of 4 to 10 hybrids at each of five sites across Iowa and Wisconsin. Plot size will vary, based on land availability, but a minimum of 30 ft. x 10 ft. will be requested for each replicated plot. The strip-trial design is popular with Midwest farmer-cooperators and has shown great promise for variety evaluation. Farmer's equipment will be for used for planting and weed management, with all field operations documented in log books provided by the project. Objective 3. Practice technology transfer. Technology transfer will be an integral part of the project. Farmer-researchers will participate in the organization and implementation of annual field days and workshops in each state to advance knowledge and skills related to plant breeding and selection. Objective 4. Develop a graduate Certificate program in Organic Plant Breeding. We will develop a graduate 3-credit course that will teach both theoretical and practical aspects of Organic Plant Breeding. This course will be embedded in a 12-credit certificate program for Organic Plant Breeding. EVALUATION The evaluation plan for this project will include an assessment of the development and implementation of improved corn germplasm for organic systems in two states, as well as the outreach efforts associated with this project. Evaluation of the overall success of these systems will be achieved through the collection of statistical data gathered throughout this 4-year project. Analyses of the experiment will be completed using SAS software. Research findings will be presented in peer-reviewed journal articles and in Extension publications, as well as at meetings widely attended by organic stakeholders. The second part of the evaluation plan will be in the form of "plant breeding and selection" and "cover crop implementation in corn systems" knowledge gain of cooperating farmers. Evaluation will rely on surveys distributed at field days and through mailings. Changes in participant's skills; If and how new skills and new knowledge are used; If attitudes and behaviors related to organic plant breeding have changed; and extent to which farmer participants felt the research and outreach addressed and integrated their concerns and feedback. Short-term outcomes will be measured by surveys distributed after field days and workshops. Baseline questions will be asked regarding the participants' current level of understanding of organic plant breeding, cover

crops, and their value. Learning outcome questions will be included to cover the information presented at the field days and workshops. Medium term outcomes will be measured through follow up interviews with field day and workshop participants. These techniques will engage farmers in a dialogue aimed at garnering their feedback to ensure the research is relevant and applicable to their situations as well as gaining a holistic understanding of the potential barriers they face in planting more diverse germplasm in their particular organic operations. Qualitative techniques, such as interviews, are integral to understanding how farmers interpret and implement best management practices. Data concerning indicators and inputs (types of crops planted, rotation cycles, cover crop practices, interest in new lines/varieties, etc.) will be gathered at annual advisory committee meetings to further interpret the short-, medium- and long-term impacts of the project. Overall project success will be measured as 1) The number of promising field and sweet corn lines or hybrids available for organic farmers in our respective states in the 3 years following the project; 2) The number of farmers adopting recommended practices deriving from this research; and 3) The number of seed companies offering organic corn varieties deriving from this research. We also will survey for this information in our annual surveys of organic farmers in our states.

**\*\*Progress\*\*** 09/01/17 to 08/31/22 **\*\*Outputs\*\*** Target Audience: Organic farmers, Organic organizations, Plant breeders, Seed producers, Seed processors Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? UW students worked with the Ga1 and Ga2 material with mentor and USDA collaborator Paul Scott in 2018, 2019, and 2020. ISU: Lauren Bilek and Megan Moore (undergraduate students), Yu-Ru Chen (Ph.D. student), and Josiah Pollock (Extension Program Specialist) were trained in on-farm experimental protocols and data analysis for this project. How have the results been disseminated to communities of interest? UW: Summer field days in Madison, WI 2019 and 2021 for organic growers. Information was presented at Midwest Food Processors Conference in Wisconsin Dells in 2019 and Organic Seed Growers Conference in Corvallis, OR in 2020. Other events interrupted by covid. ISU: besides project-specific activities, co-PI Delate is the organizer of the annual Iowa Organic Conference (November of each year in Iowa City), which allowed interactions of all project (co-)PIs and students with the organic community in Iowa and beyond. Field Days and conference presentations were utilized to disseminate information about the project. 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. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **\*\*Impacts\*\*** What was accomplished under these goals? Impact statement: In Iowa and Wisconsin, field and sweet corn lines carrying a pollen exclusion mechanism were developed, making them well-suited for organic production systems. These lines exclude foreign pollen that can carry GMOs, which would eliminate the value of organically produced seed. Moreover, a genetic mechanism for accelerated inbred line development without the need to use chemicals, as done in comparable conventional procedures, was successfully established. Both field and sweet corn prototypes were developed in this project, which can be used as donors of these genetic mechanisms in public and private organic maize breeding programs. This material is being used in two USDA OREI follow-up projects led by Drs. Scott (COOP) and Lubberstedt (CoMGI). Results from this project (ACES) were disseminated by various publications, conferences, field days, and the National Association of Plant Breeders meeting held in Ames, IA, 2022, co-hosted by (co-)PIs Lubberstedt and Scott. A graduate certificate program in Organic Plant Breeding was established and is offered at ISU. Objective 1. Field corn, BS39-derived lines: From the tropical BS39 population that was adapted by Dr. Hallauer (ISU) to Iowa conditions, more than 400 inbred lines were derived by the single seed descent (SSD) or doubled haploid (DH) approach, the latter using either colchicine for genome doubling, or a colchicine-free genetic mechanism for spontaneous haploid genome doubling (SHGD). Testcrosses of the best 50 lines were evaluated under organic conditions in two locations (Ames, Iowa and Arlington, Wisconsin) in 2019 and 2020 (Madison). Despite COVID-19 and a derecho that impacted Iowa, both 2020 trials were successfully completed, data analysis pending. In addition, a 2nd cycle breeding approach was adopted: the best two lines in terms of agronomic performance carrying the spontaneous haploid genome doubling (SHGD) ability were crossed with the 10 best lines with 100% BS39 background in summer 2019. Winter 2019/20, the haploids were induced for these crosses, and spontaneous doubling haploids selected summer 2020. More than 75 2nd generation inbreds with SHGD ability and 75% BS39 genome background were obtained. During summer 2021 season, 38 of the 2nd cycle BS39-DH lines were grown in Ames in two row plots for a first evaluation. The lines show high variability, with plant heights between 0.9 and 1.79m, and flowering times varying between 1273 to 1556 GDD. Introduction of SHGD and Ga1 into field and sweet corn (ISU): Development of donor lines in field and sweet corn carrying Ga1 and the major QTL for SHGD by marker-assisted backcrossing is proceeding as planned, and will be available by the end of this project. In Iowa and Wisconsin, sweet corn lines carrying the pollen exclusion locus Ga1 are being developed. These lines have been shown to exclude foreign pollen, making them well-suited to organic production systems where foreign pollen can carry GMOs that eliminate the value added by organic production. In Iowa, the derecho provided an opportunity for strong selection for stalk lodging. We learned that some of the germplasm developed for this program has moderate resistance to the emerging pest Fall Army Worm, providing plant breeders with a new resource to combat this pest. In addition, we proposed a molecular

model to explain the function of the pollen exclusion systems we are using in this research. This model will help breeders develop effective deployment strategies for pollen exclusion systems. The development of 50% BS39 derived materials with SHGD and Ga1 is completed in seven different backgrounds. During S2021, haploids derived from the seven completed backgrounds were evaluated for their ability to spontaneously restore male fertility. The percentage of pollen shedding tassels in these directly seeded haploid populations varied between 30 and 81%. A similar experiment with BC3 derived sweet corn introgression lines showed that MAS alone does not guarantee success for introducing the spontaneous doubling ability in these backgrounds. Phenotypic screening during the process is needed. Objectives 2 and 3: Field plot design and data collection plans for the 2022 on-farm corn variety trials were finalized in-person with farmer-cooperators in March 2022. Results from the 2021 field corn season on four farms in Iowa (NE, NC, SW, NW) were impacted by wet weather in the spring, and drought in July and August. Despite the harsh weather, high yields were achieved across all farms, with no statistical yield differences between varieties. The ranking of yields was as follows: Blue River (Ames, IA) 64K93 at 195 bu/acre; Viking 0.74-10 (Albert Lea Seed, Albert Lea, MN) at 193 bu/acre; Prairie Hybrids (Deer Grove, IL) 5141 and 4211 at 192 bu/acre; and Viking O.51-04 and Blue River 54C27 at 190 bu/acre. At the research farm site in Greenfield, IA, the organic corn yields in the longest crop rotation sequence (C-S-O/A-A) averaged 177 bu/acre, compared to the conventional yields of 130 bu/acre. Ear samples were hand-collected from each variety at physiological maturity and measured for various parameters in 2021. Corn ear weight averaged 237 g/ear with no statistical differences among varieties, but the PH 5141 tended to be heavier, at 249 g/ear. Kernel weight per ear averaged 208 g/ear across all sites and varieties, with the PH 5141 tending to be heavier, at 217 g/ear. Ear length ranged from 19 to 22 cm across all varieties, with PH 5141 averaging the longest ears at 22 cm. Insect and disease damage ratings were very low on harvested ears in 2021, averaging 1 or lower (scale of 1 to 5, with 1 2% of ear damaged) across all varieties and sites. Objective 4. A graduate certificate program in Organic Plant Breeding is offered at ISU. \*\*Publications\*\* - Type: Journal Articles Status: Published Year Published: 2021 Citation: McCluskey, C. & Tracy, W.F. (2021). Engaging Farmer Stakeholders: Maize Producers Perceptions and Strategies for Managing On-Farm Genetic Diversity in the Upper Midwest. *Sustainability*, 13: 8843, <<https://www.mdpi.com/2071-1050/13/16/8843/htm>>. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Revilla, P., Anibas, C.M. & Tracy, W.F. (2021). Sweet Corn research around the world 2015 2020. *Agronomy* 11(34). <<https://doi.org/10.3390/agronomy11030534>>. Progress 09/01/21 to 08/31/22 Outputs Target Audience: Organic farmers, Organic organizations, Plant breeders, Seed producers, Seed processors Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? During the totality of this project, these opportunities were provided: Lubberstedt: Ph.D. students Yu-Ru Chen and Mercy Fakude (Fulbright fellow) contributed to this project. Yu-Ru Chen gave poster presentations at the RF Baker symposium in Ames, IA, 2021, and at the virtual 2021 NAPB meeting. • Scott: Trained Iowa State University Ph.D. Students Amruta Bapat and Nicholas Boerman. Trained undergraduate laboratory assistant Hannah Clubb. • Tracy: MS student Cathleen McClusky finished her MS program, and continues as Ph.D. student with Dr. Tracy. • Delate: Henry Franzen, undergraduate student, was trained in on-farm experimental protocols and data analysis for this project. How have the results been disseminated to communities of interest? Lubberstedt (lecture): • Lubberstedt, T. Past, present and future of maize doubled haploid technology. Zemun Polje conference, Belgrade Serbia (virtual) June 8, 2021. • Poster presentations of group members (see above). Scott: • Information was disseminated in the following Lectures: • Scott, M.P. Using Gametophytic Incompatibility Systems to Improve Genetic Purity of Specialty Maize. Zemun Polje conference, Belgrade Serbia (virtual) June 8, 2021. • Scott, M.P. Breeding corn for organic production systems. Iowa State University Plant Breeding Seminar, May 5, 2021. • Scott, M.P. Cross incompatibility in Corn. Iowa State University Plant Biology Faculty Seminar. September 29, 2021. • Information was disseminated through the following posters at virtual scientific meetings: • Scott, M. P. (2020) The Role of Pectin Methylesterases in Gametophytic Incompatibility Systems in Maize \Abstract\, ASA, CSSA and SSSA International Annual Meetings (2020), Virtual (<https://scisoc.confex.com/scisoc/2020am/meetingapp.cgi/Paper/126705>) • Bapat, Amruta R, Moran Lauter, A.N. Hufford, M.B., Scott, M.P. 2020. Insights into the genetic architecture of the ga1 locus in maize genotypes Maize Genetics Conference Abstracts 62:P122, virtual. • URL: [https://www.maizegdb.org/data\\_center/reference?id=3230341](https://www.maizegdb.org/data_center/reference?id=3230341) Delate: • Because in-person field days were still restricted during the pandemic, a Virtual Field Day of an organic no-till corn experiment was developed as a YouTube video, which had 61 views, as of 10/15/21: <https://www.youtube.com/watch?v=qyW0EfGG-Y&t=1s> 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. Tracy: • Organology, Portland, OR. February 2019 • North Carolina State University, Raleigh, NC. June 2019 • Organic Seed Symposium, Corvallis, OR. August 2019 • Vitalis Organic Seed, San Juan Batista, CA. August 2019 • Organic Confluences. Baltimore MD. September 2019 • University of Minnesota, St. Paul, MN. September 2019. • Organic Seed Alliance, Port Townsend, WA. September 2019 • Association of University Technology Manager, St. Louis MO. September 2019. • Iowa Organic Conference Iowa City, IA, November 2019 • Diversifood, Rennes France. December 2019. • International Sweet Corn

Development Association, Chicago, IL. December 2019. • Organic Seed Growers Conference, Corvallis, OR. February 2020. • Illinois Corn Breeders School, Champaign IL. March 2020. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Objective 1. Field corn, BS39-derived lines: From the tropical BS39 population that was adapted by Dr. Hallauer (ISU) to Iowa conditions, more than 400 inbred lines were derived by the single seed descent (SSD) or doubled haploid (DH) approach, the latter using either colchicine for genome doubling, or a colchicine-free genetic mechanism for spontaneous haploid genome doubling (SHGD). Testcrosses of the best 50 lines were evaluated under organic conditions in two locations (Ames, Iowa and Arlington, Wisconsin) in 2019, and in 2020 (Madison). Despite COVID-19 and a derecho that impacted Iowa, both 2020 trials were successfully completed, with data analysis pending. In addition, a 2nd cycle breeding approach was adopted: the best two lines in terms of agronomic performance carrying the spontaneous haploid genome doubling (SHGD) ability were crossed with the 10 best lines with 100% BS39 background in summer 2019. Winter 2019/20, the haploids were induced for these crosses, and spontaneous doubling haploids selected summer 2020. More than 75 2nd generation inbreds with SHGD ability and 75% BS39 genome background were obtained. During summer 21 season, 38 of the 2nd cycle BS39-DH lines were grown in Ames in two row plots for a first evaluation. The lines show high variability, with plant heights between 0.9 and 1.79m, and flowering times varying between 1273 to 1556 GDD. Introduction of SHGD and Ga1 into field and sweet corn (ISU): Development of donor lines in field and sweet corn carrying Ga1 and the major QTL for SHGD by marker-assisted backcrossing is proceeding as planned, and will be available by the end of this project. In Iowa and Wisconsin, sweet corn lines carrying the pollen exclusion locus Ga1 are being developed. These lines have been shown to exclude foreign pollen, making them well suited to organic production systems where foreign pollen can carry GMOs that eliminate the value added by organic production. In Iowa the derecho provided an opportunity for strong selection for stalk lodging. We learned that some of the germplasm developed for this program has moderate resistance to the emerging pest Fall Army Worm, providing plant breeders with a new resource to combat this pest. In addition, we proposed a molecular model to explain the function of the pollen exclusion systems we are using in this research. This model will help breeders develop effective deployment strategies for pollen exclusion systems. The development of 50% BS39 derived materials with SHGD and Ga1 is completed in seven different backgrounds. During S2021, haploids derived from the seven completed backgrounds were evaluated for their ability to spontaneously restore male fertility. The percentage of pollen shedding tassels in these directly seeded haploid populations varied between 30 and 81%. A similar experiment with BC3 derived sweet corn introgression lines showed, that MAS alone does not guarantee success for introducing the spontaneous doubling ability in these backgrounds. Phenotypic screening during the process is needed. Objectives 2, 3: Field plot design and data collection plans for the 2022 on-farm corn variety trials were finalized in-person with farmer-cooperators in March 2022. Results from the 2021 field corn season on four farms in Iowa (NE, NC, SW, NW) were impacted by wet weather in the spring, and drought in July and August. Despite the harsh weather, high yields were achieved across all farms, with no statistical yield differences between varieties. The ranking of yields was as follows: Blue River (Ames, IA) 64K93 at 195 bu/acre; Viking 0.74-10 (Albert Lea Seed, Albert Lea, MN) at 193 bu/acre; Prairie Hybrids (Deer Grove, IL) 5141 and 4211 at 192 bu/acre; and Viking O.51-04 and Blue River 54C27 at 190 bu/acre. At the research farm site in Greenfield, IA, the organic corn yields in the longest crop rotation sequence (C-S-O/A-A) averaged 177 bu/acre, compared to the conventional yields of 130 bu/acre. Ear samples were hand-collected from each variety at physiological maturity and measured for various parameters in 2021. Corn ear weight averaged 237 g/ear with no statistical differences among varieties, but the PH 5141 tended to be heavier, at 249 g/ear. Kernel weight per ear averaged 208 g/ear across all sites and varieties, with the PH 5141 tending to be heavier, at 217 g/ear. Ear length ranged from 19 to 22 cm across all varieties, with PH 5141 averaging the longest ears at 22 cm. Insect and disease damage ratings were very low on harvested ears in 2021, averaging 1 or lower (scale of 1 to 5, with 1 2% of ear damaged) across all varieties and sites. Objective 4. A graduate certificate in Organic Plant Breeding is offered at ISU. Publications (none listed) \*\*Progress\*\* 09/01/20 to 08/31/21 \*\*Outputs\*\* Target Audience: Organic farmers, Organic organizations, Plant breeders, Seed producers, Seed processors Changes/Problems: Because of the derecho in 2020, we will use another year for on-farm trials, which will primarily require efforts from co-PI Delate. Cost-neutral extension was granted, which will in addition allow completion of data analysis and line conversion efforts by the other co-PIs. What opportunities for training and professional development has the project provided? Lubberstedt: New PhD students Yu-Ru Chen and Mercy Fakude (Fulbright fellow) joined this project. Yu-Ru Chen gave poster presentations at the RF Baker symposium in Ames, IA, 2021, and at the virtual 2021 NAPB meeting. Scott: Trained Iowa State University Ph.D. Students Amruta Bapat and Nicholas Boerman. Trained undergraduate laboratory assistant Hannah Clubb. Tracy: MS student Cathleen McClusky finished her MS program, and continues as PhD student with Dr. Tracy. Delate: Henry Franzen, undergraduate student, was trained in on-farm experimental protocols and data analysis for this project. How have the results been disseminated to communities of interest? Lubberstedt (lecture): Lubberstedt, T. Past, present and future of maize doubled haploid technology. Zemun Polje conference, Belgrade Serbia (virtual) June 8, 2021. Poster presentations of group members (see above). Scott: Information was disseminated in the following Lectures:

Scott, M.P. Using Gametophytic Incompatibility Systems to Improve Genetic Purity of Specialty Maize. Zemun Polje conference, Belgrade Serbia (virtual) June 8, 2021. Scott, M.P. Breeding corn for organic production systems. Iowa State University Plant Breeding Seminar, May 5, 2021. Scott, M.P. Cross incompatibility in Corn. Iowa State University Plant Biology Faculty Seminar. September 29, 2021. Information was disseminated through the following posters at virtual scientific meetings: Scott, M. P.(2020) The Role of Pectin Methylesterases in Gametophytic Incompatibility Systems in Maize \Abstract\, ASA, CSSA and SSSA International Annual Meetings (2020), Virtual (<https://scisoc.confex.com/scisoc/2020am/meetingapp.cgi/Paper/126705>) Bapat, Amruta R, Moran Lauter, A.N. Hufford, M.B., Scott, M.P. 2020. Insights into the genetic architecture of the ga1 locus in maize genotypes Maize Genetics Conference Abstracts 62:P122, virtual. URL: [https://www.maizegdb.org/data\\_center/reference?id=3230341](https://www.maizegdb.org/data_center/reference?id=3230341) Delate: Because in-person field days were still restricted during the pandemic, a Virtual Field Day of an organic no-till corn experiment was developed as a YouTube video, which had 61 views, as of 10/15/21: <https://www.youtube.com/watch?v=q-yW0EfGG-Y&t=1s> 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. Tracy: Organology, Portland, OR. February 2019 North Carolina State University, Raleigh, NC. June 2019 Organic Seed Symposium, Corvallis, OR. August 2019 Vitalis Organic Seed, San Juan Batista, CA. August 2019 Organic Confluences, Baltimore MD. September 2019 University of Minnesota, St. Paul, MN. September 2019. Organic Seed Alliance, Port Townsend, WA. September 2019 Association of University Technology Manager, St. Louis MO. September 2019. Iowa Organic Conference Iowa City, IA, November 2019 Diversifood, Rennes France. December 2019. International Sweet Corn Development Association, Chicago, IL. December 2019. Organic Seed Growers Conference, Corvallis, OR. February 2020. Illinois Corn Breeders School, Champaign IL. March 2020. What do you plan to do during the next reporting period to accomplish the goals?Lubberstedt and Scott: Will co-host the 2022 National Association of Plant Breeders meeting at Iowa State University (August 8-11, 2022). This in-person event will offer the possibility to engage with stakeholders, and to show case outcomes of this USDA OREI project, e.g., during the planned field tour, and by student poster presentations. Lubberstedt: Will finish analysis of data from this project for publication. Moreover, development of field and sweet corn lines carrying SHGD and Ga1 will be completed. This materials will be used in ongoing USDA OREI projects COOP and CoMGI. 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. Field Days will be held on two on-farm sites in 2022. \*\*Impacts\*\* What was accomplished under these goals? Objective 1. Develop novel organic field corn and sweet corn genotypes for the commercialization pipeline that utilize more efficient methods of breeding. Field corn, BS39-derived lines: From the tropical BS39 population that was adapted by Dr. Hallauer (ISU) to Iowa conditions, more than 400 inbred lines were derived by the single seed descent (SSD) or doubled haploid (DH) approach, the latter using either colchicine for genome doubling, or a colchicine-free genetic mechanism for spontaneous haploid genome doubling (SHGD) (Verzegnazzi et al. 2021; Santos et al. 2021). A 2nd cycle breeding approach was adopted: the best two lines in terms of agronomic performance carrying SHGD ability were crossed with the 10 best lines with 100% BS39 background. Winter 2019/20, the haploids were induced for these crosses, and spontaneous doubling haploids selected summer 2020. More than 75 2nd generation inbreds with SHGD ability and 75% BS39 genome background were obtained, seed was multiplied winter 2020/21. Introduction of SHGD and Ga1 into field and sweet corn (ISU): Development of donor lines in field and sweet corn carrying Ga1 and the major QTL for SHGD by marker-assisted backcrossing is proceeding as planned, and will be available by end of this project. In Iowa and Wisconsin, sweet corn lines carrying the pollen exclusion locus Ga1 are being developed. These lines have been shown to exclude foreign pollen, making them well suited to organic production systems where foreign pollen can carry GMOs that eliminate the value added by organic production. In Iowa the derecho provided an opportunity for strong selection for stalk lodging. We learned that some of the germplasm developed for this program has moderate resistance to the emerging pest Fall Army Worm, providing plant breeders with a new resource to combat this pest. In addition, we proposed a molecular model to explain the function of the pollen exclusion systems we are using in this research. This model will help breeders develop effective deployment strategies for pollen exclusion systems. 2021 progress Field corn, BS39-derived lines: During summer 21 season, 38 of the 2nd cycle BS39-DH lines were grown in Ames (and by collaborator Dr. Bohn, UIUC in Champaign) in 2-row plots. Lines were uniform, plant heights varying between 0.9 and 1.79m, and flowering times between 1273 to 1556 GDD. Data from UIUC have been provided and will be jointly analyzed. In the frame of the USDA OREI project CoMGI, crosses conducted between those lines will be sent to the winter nursery in Puerto Rico, and haploids induced. Haploids will be planted in Ames '22, to develop improved BS39-derived breeding materials. Introduction of SHGD and Ga1 into field and sweet corn (ISU): The development of 50% BS39 derived materials with SHGD and Ga1 is completed in seven different backgrounds, and still ongoing for another three backgrounds. During S2021, haploids derived from the seven completed backgrounds were evaluated for their ability to spontaneously restore male fertility. The percentage of pollen shedding tassels in these directly seeded

haploid populations varied between 30 and 81%. A similar experiment with BC3 derived sweet corn introgression lines showed, that MAS alone does not guarantee success for introducing the spontaneous doubling ability in these backgrounds. Phenotypic screening during the process is needed. The SHGD donor was crossed to seven sweet corn inbred lines, and the respective F1s will be backcrossed to the respective inbred lines (Dr. Tracy) and haploid induced (ISU DH Facility) during winter of 2021/22. Resulting haploids will be evaluated for SHGD during summer of 2022. We are developing sweetcorn with improved genetic purity by transferring the Ga2 allele into sweet corn lines. This year we advanced breeding lines with selection for the ability to exclude unwanted pollen and agronomic properties. Interestingly, we observed several lines that were unexpectedly able to cross with lines that should have excluded their pollen, suggesting that our model for function of gametophytic incompatibility systems requires revision. We developed a new hypothesis to explain these data. We suspect that there is interaction between different gametophytic incompatibility systems. An alternative hypothesis is that the function of gametophytic incompatibility systems is dependent on environmental conditions. We have initiated experiments to test these hypotheses. These results will enable to develop corn varieties with improved genetic purity, reducing the impact of GMO contamination on organic corn producers.

**Objective 2.** Select and test on-farm genotypes that meet the critical needs of organic producers. In 2021, six commercial organic field corn varieties (BR 54C27, BR 64K93, Prairie Hybrids 4211, Prairie Hybrids 5141, Viking 0.51-04, and Viking 0.74-10) were compared, with one farm (NC) also evaluating the USDA hybrid, 5323219. Plant emergence across the four on-farm sites ranged from 28,300 plants/acre at the NE site to 33,667 plants/acre at the SW site. Mid-season commercial organic corn plant height varied across varieties and sites, with the Blue River 54C27 variety the tallest at 273 cm, compared to the lowest average height in the Prairie Hybrids 5141 variety at 257 cm. Weed populations were managed well in 2021 across all sites with grass weeds in mid-June ranging from 0 weeds/sq. foot at the SW site to 6 weeds/sq. foot at the NE site. Broadleaf weeds averaged 0 weed/sq. foot at the SW site to 2 weeds/sq. foot at the NE site. Correlations between weed populations and yields will be conducted after all plots are harvested in 2021.

**Objective 3.** Practice technology transfer through a network with organic farmers and organic seed companies. Field plot design and data collection plans for the 2021 on-farm corn variety trials were finalized in-person with farmer-cooperators. The 2020 field corn season on four farms in Iowa (NE, NC, SW, NW) was very challenging, with wet weather in the spring, drought in July and August, and a derecho in August. Despite the harsh weather, Viking 0.18-06 UP (Albert Lea Seed, Albert Lea, MN) and Viking 0.51-04 produced the highest yields, at 168 bu/acre and 166 bu/acre, respectively, across the four on-farm sites. Blue River 48G35 and 57A30 varieties averaged 161 bu/ac and 163 bu/ac, respectively. A USDA hybrid (19MPS/19SJWF) showed competitiveness with commercial hybrids, at 147 bu/acre; the other USDA hybrid (19SJWE/185MPS) was lower at 114 bu/acre. Despite 100 mph winds from the derecho, commercial organic hybrid yields at the most affected farm (North Central Iowa) were exceptional, averaging 165 bu/acre. Ear samples were hand-collected from each variety at physiological maturity and measured for various parameters in 2020. Corn ear weight averaged 200 g/ear for the BR57A30 variety, while the Viking 0.18-06 UP averaged 239 g/ear across all sites. Kernel weight per ear averaged 172 g/ear for the BR48G35 variety while the Viking 0.18-06 UP averaged 209 g/ear across all sites. Ear length ranged from 18 to 21 cm, with Viking 0.18-06 UP averaging the longest ears at 21 cm. Kernel weight in the USDA varieties ranged from 175 to 192 g/ear, with ear length ranging from 18 to 19 cm. Insect and disease damage ratings were very low on harvested ears in 2020, averaging less than 1 (scale of 1 to 5, with 1 2% of ear damaged) across all varieties and sites.

**Objective 4.** Develop a graduate Certificate program in Organic Plant Breeding. The "Organic Plant Breeding" certificate program is available at ISU (<https://www.agron.iastate.edu/graduate-department/new-organic-plant-breeding-certificate>). A student in the Distance MS program at ISU (Christy Montes) developed materials in her creative component (defense 11/2020), which will be used in the organic plant breeding course. Another student (Lawrence Warnock) will do the same in prepare his creative component spring 2022.

**\*\*Publications\*\*** - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Delate, K. (2021) Surviving COVID, Derecho, and Drought Lessons from 2020- Midwest Organic and Sustainable Education Service (MOSES) Organic Conference, La Crosse, WI, 2/25/21  
<https://www.dropbox.com/s/lgceptpiwih34vp/Surviving%20COVID%2C%20Derecho%2C%20and%20Drought%20Lessons%20of%20Resilience%20in%202020%20edited.mp4?dl=0> - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Delate, K. (2021) Risk Management for Organic Production: March 10, 2021, ISU-FFED, Ames, IA <https://www.extension.iastate.edu/ffed/specialty-crops-risk-management-webinar-series/> - Type: Other Status: Other Year Published: 2021 Citation: Delate, K. (2021) Grain Place Foundation Field Day, July 17, 2021 <http://www.grainplacefoundation.org/news/> - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Delate, K. (2021) NRCS Webinar: Organic Research to Support Transitioning, February 18, 2021, Des Moines, IA - Type: Journal Articles Status: Published Year Published: 2021 Citation: Verzegnazzi, A., Goncalves, I., Frei, U.K., Krause, M., Campbell, J., Almeida, V., Tonello Zuffo, L., Boerman, N., Løbberstedt, 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: Other

Year Published: 2021 Citation: Goncalves, I., Verzegnazzi, A.L., Edwards, J., Frei, U.K., De La Fuente, G.N., Zuffo, L., Pires, L.P.M., Lubberstedt, T. (2021) Usefulness of Adapted Exotic Maize Lines Developed By Doubled Haploid and Single Seed Descent Methods. (<https://www.researchsquare.com/article/rs-799789/v1>) - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Thomas Lubberstedt, Siddique Muhammad-Aboobucker, Tanner Cook, Yu-Ru Chen, Mercy Fakude, Liming Zhou, Elizabeth Bovenmyer, Sarah Pfeffer, Ursula Karoline Frei. Past, present, and future of maize doubled haploid technology. Conference "The Frontiers of Science and Technology in Crop Breeding and Production", Zemun Polje, Belgrade. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Zystro, Jared, Tessa Peters, Kathleen Miller, and William F. Tracy 2021. Inbred and hybrid sweetcorn genotype performance in diverse organic environments. *Crop Science* 10.1002/csc2.20457 - Type: Journal Articles Status: Published Year Published: 2021 Citation: Solemslie, R., du Toit, L.J., Tracy, W.F., and Stearns, T. 2021. Evaluation of steam treatments for *Fusarium* spp. and other fungi on sweet corn seed, 2021. *Plant Disease Management Reports* 15:CF017. - Type: Journal Articles Status: Accepted Year Published: 2021 Citation: Muhammad-Aboobucker, S., Jubery, Z., Frei, U.K., Foster, T., Chen, Y.-R., Ganapathysubramanian, B., Lubberstedt, T. (2021) Protocols for in vivo doubled haploid (DH) technology in maize breeding: From haploid inducer to haploid genome doubling. *Methods Molecular Biology* (in press) - Type: Journal Articles Status: Published Year Published: 2021 Citation: Zystro, Jared, Tessa Peters, Kathleen Miller, and William F. Tracy 2021. Classical and genomic prediction of synthetic open pollinated sweet corn performance in organic environments. *Crop Science* <https://doi.org/10.1002/csc2.20531> - Type: Journal Articles Status: Published Year Published: 2021 Citation: McCluskey, C. and W.F. Tracy. 2021. Engaging Farmer Stakeholders: Maize Producers Perceptions and Strategies for Managing On-Farm Genetic Diversity in the Upper Midwest. *Sustainability* <https://www.mdpi.com/2071-1050/13/16/8843/htm> - Type: Journal Articles Status: Accepted Year Published: 2021 Citation: Boerman, N., Moran Lauter, A.N., Scott, M.P. (2020) Variation in degree of pollen exclusion for Ga1-s unilateral cross incompatibility in temperate maize breeding populations, *Agrosystems, Geosciences & Environment* (In Press). - Type: Theses/Dissertations Status: Published Year Published: 2020 Citation: Boerman, N. (2020) Genetic analysis of doubled haploid and unilateral cross incompatibility systems for organic maize breeding, Ph.D. Thesis Iowa State University Department of Agronomy. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Zystro, Jared, Tessa Peters, Kathleen Miller, and William F. Tracy 2020. Classical and genomic prediction of hybrid sweet corn performance in organic environments. *Crop Science* 10.1002/csc2.20400 - Type: Journal Articles Status: Published Year Published: 2020 Citation: Moore, Virginia M. and Tracy, William F. 2020. Combining ability of husk extension, maysin content, and corn earworm resistance. *Journal of American Society of Horticultural Science* 146:14-23. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Moore, Virginia M. and Tracy, William F. 2020. Survey of organic sweet corn growers identifies corn earworm prevalence, management, and opportunities for plant breeding. *Renewable Agriculture and Food Systems* pp. 1-4 DOI: <https://doi.org/10.1017/S1742170520000204> - Type: Theses/Dissertations Status: Published Year Published: 2020 Citation: McCluskey, C.A. 2020. Corn in the upper Midwest: farmers perceptions and strategies for managing on-farm genetic diversity. Master of Science Thesis. University of Wisconsin-Madison - Type: Other Status: Published Year Published: 2020 Citation: Delate, K. (2020) Small Farm Sustainability Podcast: Iowa Organic Update, November 11, 2020, Iowa State University, Ames, IA <https://www.extension.iastate.edu/smallfarms/small-farm-sustainability-podcasts> - Type: Conference Papers and Presentations Status: Other Year Published: 2020 Citation: Delate, K. (2020) Hort 530 Lecture: Update on Organic Research: Nov. 17, 2020, ISU Dept. of Horticulture, Ames, IA - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Delate, K. (2020) Iowa Organic Conference, Nov. 23, 2020, ISU Dept. of Horticulture, Ames, IA: [https://www.iowaorganic.org/2020\\_iowa\\_organic\\_conference](https://www.iowaorganic.org/2020_iowa_organic_conference) - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Delate, K. (2020) OATS (Organic Agronomy Training Series) Podcast: The Dirt on Organic Farming <https://www.organicagronomy.org/the-dirt-on-organic-farming>

## PROGRESS

2017/09 TO 2018/08 Target Audience: Organic farmers, Organic organizations, Plant breeders, Seed producers, Seed processors Changes/Problems: Objective 4 is delayed. While a syllabus for the new course on "Organic Plant Breeding" is in place, and its approval ongoing, the time needed for the administrative process to (a) get this new course approved, and (b) the certificate program, was underestimated. We currently plan to offer this course for a first time spring 2020, which is 6 months later than mentioned in the project description. On the positive side, we gained approval for development and offering this course far beyond duration of the ongoing project. Thus, once developed it will be available through the distance education in plant breeding platform at ISU. What opportunities for training and professional development has the project provided? Dr. Lubberstedt trained Ph.D. student Nicholas Boerman. Nicholas (Nick) Boerman is an Iowa State University graduate student in the plant breeding program. Nick received his M.Sc. degree in plant breeding at Texas A & M University, where

he took fundamental courses in plant breeding, genetics and statistics. At ISU, he is taking more advanced classes on these topics, as well as on molecular genetics and genomics and bioinformatics. In addition, he participated in the R.F. Baker Symposium (Plant Breeding) at ISU in March 2018, and attended a summer workshop on Python and R programming this summer (in NSF P3 program). Nick's research addresses doubled haploid (DH) technology, specifically spontaneous haploid genome doubling, and its introgression into field and sweet corn. Nick has been exposed to all steps of DH technology as part of his field nursery work, also attended a DH workshop at ISU this summer. Nick prepared a research proposal, which he presented to his program of study committee. He already passed two out of five written prelims, aiming for completing all prelims within the next year. Dr. Scott trained Ph.D. student Amruta Bapat and undergraduate student Taylor Hintch. Taylor Hintch is an Iowa State University undergraduate student majoring in Global Resource Systems. As an hourly worker in this project, she receives training in corn genetics, participating in all aspects of the nursery operation, including planting, pollinating, harvesting, and inventorying seed. In addition, she has her own research project that involves characterization of a series of doubled haploid maize lines with enhanced nutritional quality. In this project, she learned fundamentals of experimental design and laboratory methods for evaluating nutritional quality. She prepared a poster and presented her results at the Borlaug Lecture poster contest at Iowa State University, where she won first prize in the Undergraduate division. Amruta Bapat is an Iowa State University graduate student in the Interdepartmental genetics and genomics graduate program. She receives training in maize genetics and molecular biology by assisting with shared nursery operations and carrying out her thesis research. Her thesis project involves understanding the molecular mechanism controlling pollen exclusion in the Ga1 genetic system. In this research she has learned bioinformatics analysis, and molecular biology methods such as DNA manipulations and heterologous gene expression. Dr. Tracy trained Ph.D. student Cathleen McCluskey. Cathleen McCluskey is a masters degree candidate in the interdepartmental Agroecology Program at University of Wisconsin-Madison. In this project, she receives training in maize genetics, disease identification, experimental design, statistics, and nursery operation, including planting, pollinating, and harvesting seed. Her thesis work involves measuring and assessing genetic diversity in U.S. maize. How have the results been disseminated to communities of interest? A first stakeholder meeting with representatives from plant breeding companies, seed producers, seed processors, and organic organization was held at the beginning of the USDA OREI ACES project in December 2017, in conjunction with the ASTA meeting in Chicago. Project co-PIs presented the planned activities within the four project objectives, which were subsequently critically discussed. A follow-up meeting is planned December 2018 in conjunction with ASTA, combined with a meeting of the US testing network (USTN). One of the most critical aspects of this component of ACES was the buy-in from project farmers to maintain the variety trial fields in excellent condition throughout the season and their assistance with data collection. This shows great promise for their continued involvement in evaluating new lines that are developed from the ACES pipeline. Taylor Hintch presented a poster titled "Analyzing doubled haploids using a microbial assay to identify high methionine lines" at the Borlaug Lecture Poster Session (Ames, Iowa, October 15, 2018) and won first prize in the undergraduate poster contest. A report of the sweet corn portion will be given at the international sweet corn development association annual meeting in December. What do you plan to do during the next reporting period to accomplish the goals? Dr. Lubberstedt: In the 2nd year of the project, we will evaluate testcrosses of BS39 inbred lines under organic field conditions at the ISU Agronomy farm. We will continue our introgression program of qSHGD1 and Ga1 into 10 BS39 and 3 sweet corn-derived lines by backcrossing. We hope to complete the approval process of the "organic plant breeding" course and respective certificate program, and initiate course development for a first offering spring 2020. We will prepare first publications on characterization of BS39 inbred lines, and report findings at different conferences and meetings (ICSDA, stakeholder meeting, PAG, MOSES, MGC, Corn Breeder school, ..). Dr. 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. Field Days will be held on at least two on-farm sites in 2019. Dr. Scott: We will continue to study the inheritance of gametophytic incompatibility systems in different families of maize in order to develop a selection strategy that effectively transfers the trait to desired varieties. Our current focus is on understanding genotypic variation in pollen exclusion, and genotype-dependent variation in gene action. We will evaluate hybrids derived from high methionine doubled haploid lines to identify those with superior agronomic traits. Dr. Tracy: We will continue to work with the over 50 unique crosses between sweet corn genotypes and Ga1 or Ga2. These crosses have been sent to winter nurseries where they will be self pollinated generating 50 F2 populations from which we will derive new inbreds.

2018/09 TO 2019/08 Target Audience: Organic farmers, Organic organizations, Plant breeders, Seed producers, Seed processors Changes/Problems: Objective 1: after testing 400 inbred lines derived from the BS39 population in 2018, we noticed wide genetic variation for agronomic traits in this tropical-adapted materials. We decided, after discussions among project participants and with board members December 2018, to deviate from the original approach to re-test all 400 lines in 2019. Instead, we employed a breeder's approach of re-testing only

the 50 best lines, while already producing the 2nd cycle of breeding materials after crossing the best lines. 2nd cycle DH lines will be available in 2020, and evaluated in the last year of this project in 2021. What opportunities for training and professional development has the project provided?

Amruta Bapat is a graduate student in the Interdepartmental Genetics and Genomics program at Iowa State University who was supported full time by this grant. This year, in addition to her normal course work, she participated in the following activities: 1. Attended ASTA CSS 2018 and Seed expo held between Dec 3-6, 2018, Chicago and presented poster titled "A molecular model for the *ga1* locus in maize genotypes". 2. Attended USTN annual meeting on December 4th 2018. 3. Attend the 6th Annual R. F. Baker Plant Breeding Symposium at ISU on 1st March 2019 and presented poster titled "A molecular model for the *ga1* locus in maize genotypes". 4. Attended and presented poster titled "Analysis of a cluster of *ZmPME3* pseudogenes at the maize Gametophytic Incompatibility 1 (*Ga1-s*) locus" at Corn breeding research meeting between March 13-14, 2019 at St. Louis. 5. Attended and presented poster titled "Analysis of a cluster of *ZmPME3* pseudogenes at the maize Gametophytic Incompatibility 1 (*Ga1-s*) locus" at the Annual Maize Genetics Conference between March 14-17th 2019 at St. Louis. 6. Participated in the 3-day hands on Plant CRISPR Workshop held between May 13-15, 2019 at Crop Bioengineering center at Iowa State University.

Nicholas (Nick) Boerman is an Iowa State University graduate student in the plant breeding program, supported full time by this project. In addition to his course work, he participated in the activities 1. - 3. mentioned above. In addition, he gave an oral presentation at the ICSDA sweet corn meeting in Wisconsin, 2018, and he will have an oral presentation at the ASA/CSSA meeting 2019 in San Antonio.

Dr. Anderson Verzegnazzi was a graduate student in the plant breeding program at ISU. Even though not covered by this project, he developed the BS39-derived inbred lines used in this project, and was involved in the 2018 field trials. Anderson defended in July 2019, and is meanwhile working as plant breeder for KWS Saat AG in his home country Brazil.

Dr. Tracy trained Ph.D. student Cathleen McCluskey. Cathleen McCluskey is a masters degree candidate in the interdepartmental Agroecology Program at University of Wisconsin-Madison. In this project, she receives training in maize genetics, disease identification, experimental design, statistics, and nursery operation, including planting, pollinating, and harvesting seed. Her thesis work involves measuring and assessing genetic diversity in U.S. maize. Drs. Scott and Lubberstedt hosted two Ph.D. students from Khon Kaen University in Thailand who are working on adding value to specialty corn varieties by developing pigmented varieties.

Mr. Prakasit Duangpapeng and Ms. Ponsawan Khamphason worked with project members to carry out field operations this summer. They learned about all aspects of field operations including planning, organization, planting, pollinating, data collection, and harvest. How have the results been disseminated to communities of interest? Results were shared with cooperators scientific meetings including the ASTA Corn and Soybean expo (December 4-6, 2018, Chicago, IL) and the Maize Genetics conference (March 14-17, 2019, St. Louis, Mo.)

Nick Boerman he gave an oral presentation at the ICSDA sweet corn meeting in Wisconsin, 2018, and he will have an oral presentation at the ASA/CSSA meeting 2019 in San Antonio. A Field Day was held at the ISU Neely-Kinyon Farm in Greenfield, Iowa, on August 20, where the OREI project was presented and discussed with 52 participants.

Dr. Scott presented a talk on corn inbreds, hybrids and triple crosses for organic production systems. On November 25, a workshop on the project and the state of organic seed in the U.S. will be held at the Iowa Organic Conference in Iowa City, Iowa. We continue to have buy-in from project farmers to grow the specific varieties or lines, and assist with data collection during the season. A new farmer from SW Iowa will participate in 2020. This shows great promise for their continued involvement in evaluating new lines that are developed from the ACES pipeline.

Dr. Tracy and Cat McCluskey hosted a group of organic farmers from Germany and the USA. We toured the ISU plots grown in Wisconsin and gave a presentation on this project. They were 19 attendees.

Dr. Tracy presented at talk at the UW-Madison organic cropping field day, Arlington Wisconsin August 29, 2019. There were approximately 60 attendees. What do you plan to do during the next reporting period to accomplish the goals?

Dr. Lubberstedt: In the 3rd year of the project, we will evaluate testcrosses of BS39 inbred lines under organic field conditions at the ISU Agronomy farm and in Wisconsin (2nd year in both cases). We will continue our introgression program of *qSHGD1* and *Ga1* into 10 BS39 and 3 sweet corn derived lines by backcrossing. We hope to complete the approval process of the "organic plant breeding" certificate program, and initiate course development for a first offering fall 2020. We will prepare first publications on characterization of BS39 inbred lines, and report findings at different conferences and meetings (ICSDA, stakeholder meeting, MOSES, MGC, Corn Breeder school, ..).

Dr. 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. Field Days will be held on at least two on-farm sites in 2020.

Dr. Scott: We will continue to study the inheritance of gametophytic incompatibility systems in different families of maize in order to develop a selection strategy that effectively transfers the trait to desired varieties. Our current focus is on understanding genotypic variation in pollen exclusion, and genotype-dependent variation in gene action. We will evaluate hybrids derived from high methionine doubled haploid lines to identify those with superior agronomic traits.

Dr. Tracy: We will evaluate the progenies being developed for pollen exclusion and SHGD and sweet corn characteristics. We will also grow locations of the ISU trials and supply

sweet corn cultivars to interested participants. We will continue our trials on ways to improve organic production of hybrid corn seed.

2019/09 TO 2020/08 Target Audience: Organic farmers, Organic organizations, Plant breeders, Seed producers, Seed processors Changes/Problems: 2020 certainly was/is an unusual year severely impacted by the COVID-19 pandemic, and in Iowa: a major wind event (derecho). This led to university closures after spring break 2020, and reduced research activities in laboratories and research farms. Nonetheless, both ISU, USDA and U Wisconsin were able to continue their field research and nursery activities, while overall reduced, field activities for this project were not affected and continued as planned. The derecho reduced nursery harvest at ISU somewhat, but not dramatically. The BS39 field trial at ISU was impacted, but again, the wind event may even be helpful to differentiate lines with regard to lodging tolerance. What opportunities for training and professional development has the project provided? Overall, opportunities in 2020 were more limited due to the COVID-19 pandemic. One of the last in person events was the RF Baker Symposium at ISU with student poster presentations. Amruta Bapat is an Iowa State University Graduate student in the Interdepartmental Genetics and Genomics degree program. She carried out research on the molecular genetics of gametophytic incompatibility. She presented her results in a poster at the 2020 virtual Maize Genetics Conference. Nicholas (Nick) Boerman is an Iowa State University graduate student in the plant breeding program, and gave an oral presentation at the ASA/CSSA meeting 2019 in San Antonio. Dr. Tracy trained Ph.D. student Cathleen McCluskey. Cathleen McCluskey is a masters degree candidate in the interdepartmental Agroecology Program at University of Wisconsin-Madison. In this project, she receives training in maize genetics, disease identification, experimental design, statistics, and nursery operation, including planting, pollinating, and harvesting seed. Her thesis work involves measuring and assessing genetic diversity in U.S. maize, which resulted in a MS thesis in 2020. Drs. Henrique Trentin and Arthur Pereira were graduate students in the plant breeding program at ISU. Even though not covered by this project, both contributed to research relevant for this project. Henrique was involved in haploid inducer development, and Arthur in studying spontaneous haploid genome doubling. Both defended in 2019, and are meanwhile working in their home country Brazil for Bayer and Stine, respectively. How have the results been disseminated to communities of interest? Because no in-person field days were permitted during the pandemic, a Virtual Field Day of the organic experiments at the ISU Neely-Kinyon Farm in Greenfield, Iowa, was developed as a YouTube video, which had 298 views, as of 10/15/20: <https://www.youtube.com/watch?v=P PpIV5EmT4> 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. Results were published in scientific journals. Other presentations: Scott Presented invited talk at University of Illinois, Urbana -Champaign "Breeding corn for organic production systems" November 21, 2019. Poster at organic seed growers conference Poster at MOSES What do you plan to do during the next reporting period to accomplish the goals? Lubberstedt: Analyze BS39 data, evaluate 2nd cycle lines in summer of 2021. Initiate the certificate in organic plant breeding. Scott: We plan to advance Ga2 breeding lines with selection for Agronomic traits and pollen exclusion. We will continue to characterize pollen exclusion systems both biochemically and genetically to gain a better understanding of how to use these systems to preserve the genetic purity of corn varieties. 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. Field Days will be held on at least two on-farm sites in 2021. Tracy: Wisconsin will advance Ga1 material and continue to evaluate efficacy of pollen exclusion in sweet corn. We will continue working with Ames on moving the SHGD into sweet corn.

## IMPACT

2017/09 TO 2018/08 What was accomplished under these goals? Overall impact statement: The overall goal of the project is to substantially increase the productivity of organic field and sweet corn production within organic crop rotations, by improving the efficiency of breeding through doubled haploid (DH) technology and traditional breeding methods, focused on early plant vigor and competitiveness factors. Another goal is to develop a Certificate program in Organic Plant Breeding, which can be accessed online in the U.S. and internationally. All project partners conducted field experiments for evaluation of maize lines under organic conditions, and / or breeding work to develop novel germplasm. For example, 400 lines developed for this project were evaluated in six environments. Superior lines with regard to agronomic performance under organic conditions and for quality traits were identified. These superior lines will receive by conventional crosses additional properties which will make future breeding of organic maize varieties more efficient. A major finding was that an important property for DH technology is simple inherited (one single major gene), which will simplify breeding strategies to incorporate this property into elite breeding materials. Our findings will lead to changes in knowledge and action in the way

breeding of organic field and sweet corn will be done in future, by using DH technology and the novel genetic property characterized in this project. Outcomes will be first generation field and sweet corn lines carrying this property along with another important trait (cross-incompatibility) employed in this project. Stakeholders will be engaged to evaluate first prototypes under organic practice conditions, to determine robustness of these materials. The certificate program on Organic Plant Breeding to be established in this program will be a venue, to share new knowledge in the field of organic plant breeding with students, working professionals, and others engaged in this topic. Strengthened organic plant breeding will lead to better adapted and more competitive varieties under organic conditions, which benefits farmers but also the general public, as this should impact prices of organic products.

**Objective 1. Develop novel organic field corn and sweet corn genotypes for the commercialization pipeline that utilize more efficient methods of breeding.** Field corn, BS39-derived lines: From the tropical BS39 population that was adapted by Dr. Hallauer (ISU) to Iowa conditions, 400 inbred lines were derived by the single seed descent (SSD) or doubled haploid (DH) approach, the latter using either colchicine for genome doubling, or a colchicine-free genetic mechanism for spontaneous haploid genome doubling (SHGD). These 400 lines were evaluated at per se level in three environments in Iowa, including one organic location at the ISU Agronomy farm. Moreover, testcross trials with those same 400 lines were conducted under conventional conditions (4 locations), and will be conducted under organic conditions at the ISU Agronomy farm in 2019, and 2020. All field BS39-experiments for 2018 have been completed and harvested. Respective data are under analysis and will be presented at the stakeholder meeting in December 2018.

Field corn, quality protein maize: Methionine is an important nutrient in the diets of poultry. Most poultry diets in the US are based on corn, and synthetic methionine is added to meet the nutritional needs of the birds. Organic standards limit the level of synthetic methionine in poultry diets, so corn with levels of methionine that are high enough to offset the need for supplementation are desirable. High methionine field corn lines produced by doubled haploid technology were evaluated per se for their ability to produce high grain methionine levels. Five lines were identified that had significantly higher methionine levels than the high methionine inbred check. These lines have the highest level of methionine of any inbred observed to date. The lines with the highest levels of methionine were used to make hybrid seed that will be evaluated in yield trials next year. Hybrids of high methionine lines and commercial inbreds were observed for the purpose of assigning them to heterotic groups. We concluded that these inbreds combine equally well with stiff stalk and non-stiff stalk commercial inbreds, making them desirable for use as hybrid parents.

Introduction of SHGD and Ga1 into field and sweet corn (ISU): Genetic mapping experiments at ISU revealed, that a single major QTL (qSHGD1) explains more than 50% of the phenotypic variation for SHGD. A donor line fixed for qSHGD1 and cross-incompatibility gene Ga1 for pollen control has been completed. Moreover, crosses and marker-assisted backcrosses have been initiated to develop 10 BS39- and 3 sweet corn-derived lines carrying both qSHGD1 and Ga1. Dr. Tracy evaluated in a four replication inbred trial selected BS39 lines that were chosen for this conversion program under organic conditions at West Madison WI. He supplied performance data to the originators at ISU.

Sweet corn (Wisconsin): We have made over 50 unique crosses between sweet corn genotypes and Ga1 or Ga2. These crosses have been sent to winter nurseries where they will be self-pollinated generating 50 F2 populations from which we will derive new inbreds.

**Objective 2. Select and test on-farm genotypes that meet the critical needs of organic producers.** On-farm trials for field corn: There were two sets of variety trials with farmer involvement in 2018. Field plot design and data collection were finalized at a project farmer meeting at the MOSES conference on February 23, 2018. The first trial was at the ISU Neely-Kinyon Farm in Greenfield, Iowa (southwest Iowa), where four USDA lines were compared to the native 'Meskwaki Tama Flint' (MTF) corn, which was secured from a member of the Meskwaki Nation. The second set of trials was conducted on five farms-four in Iowa (field corn) and one in Minnesota (sweet corn). The USDA lines, averaging 123 bu/acre, with the 393 line more competitive at 138 bu/acre, compared well with the commercial organic variety (Viking 79-08, Albert Lea, MN), which yielded 173 bu/acre. We are currently calculating grain quality from ear samples from all sites. Organic producers need corn varieties that differ from those used in conventional agriculture systems. They must be GMO-free, have native resistance to insect pests and pathogens, and compete effectively with weeds. Hybrids with traits desired by organic producers were identified from germplasm developed under a 2014 NIFA - OREI grant. Seed of these hybrids was produced in sufficient quantity to share with farmers next year.

**Objective 3. Practice technology transfer through a network with organic farmers and organic seed companies.** One of the most critical aspects of this component of ACES was the buy-in from project farmers to maintain the variety trial fields in excellent condition throughout the season and their assistance with data collection. This shows great promise for their continued involvement in evaluating new lines that are developed from the ACES pipeline. Dr. Tracy gave a field tour to a group from one of the major organic seed sales companies and we have also carried out trials with major organic hybrid seed producer.

**Objective 4. Develop a graduate Certificate program in Organic Plant Breeding.** A syllabus for the novel course 'Organic Plant Breeding' has been established. The course is currently routing in the ISU approval process. An important initial step, the head of Department of Agronomy approved development and continuous offering of this course, which requires resources beyond this ongoing USDA OREI project ACES. Currently, approval is requested from the College of Agriculture and Life Science curriculum committee. Once the approval process is completed,

actual course development will commence, targeted for a first offering spring 2020. \*\*PUBLICATIONS (not previously reported):\*\* 2017/09 TO 2018/08 1. Type: Journal Articles Status: Published Year Published: 2017 Citation: De La Fuente, G.N., Carstensen, J.M., Edberg, M.A., L?bberstedt, T. (2017) Discrimination of haploid and diploid maize kernels via multispectral imaging. *Plant Breeding* 136:50-60 2. Type: Journal Articles Status: Published Year Published: 2017 Citation: Wu, P., Ren, J., Tian, X., Li, G., Li, W., L?bberstedt, T., Wang, L., Liu, W., Chen, S. (2017) New insights into the genetics of haploid male fertility. *Crop Sci.* 57:637-647 3. Type: Journal Articles Status: Published Year Published: 2017 Citation: Vanous, K., Vanous, A., Frei, U.K., L?bberstedt, T. (2017) Generation of maize (*Zea mays*) doubled haploids via traditional methods. *Current Protocols in Plant Biology* 2: 147-157 4. Type: Journal Articles Status: Published Year Published: 2017 Citation: Wang, C., Hu, S., Gardner, C., L?bberstedt, T. (2017) Emerging avenues for utilization of exotic germplasm. *TIPS* 22: 624-637 5. Type: Journal Articles Status: Published Year Published: 2017 Citation: Ren, J., Wu, P., Tian, X., L?bberstedt, T., Chen, S. (2017) Fine mapping of quantitative trait locus qhmf4 causing haploid male fertility in maize based on segregation distortion. *Theor. Appl. Genet.* 130:1349?1359 6. Type: Journal Articles Status: Published Year Published: 2017 Citation: Ren, J., Wu, P., Trampe, B., L?bberstedt, T., Chen, S. (2017) Novel technologies in doubled haploid line development. *Plant Biotech J.* 15: 1361-1370 7. Type: Conference Papers and Presentations Status: Other Year Published: 2018 Citation: ?On-Farm Organic Corn Trials? ? Farmer-Cooperator Meeting, Midwest Organic and Sustainable Education Service (MOSES) Organic Conference, La Crosse, WI, 2/24/18 8. Type: Conference Papers and Presentations Status: Other Year Published: 2018 Citation: ?Organic Research in Iowa? - Horticulture Dept., University of Florida, Gainesville, FL, 3/14/18 9. Type: Conference Papers and Presentations Status: Other Year Published: 2018 Citation: ?Organic Research Update ? OREI ACES Project? ? ISU Neely-Kinyon Farm Field Day, Greenfield, IA, 8/12/18, K. Delate and Paul Scott 10. Type: Journal Articles Status: Published Year Published: 2018 Citation: Vanous, A., Gardner, C., Blanco, M., Martin-Schwarze, A., Flint-Garcia, S., Bohn, M., Edwards, J., L?bberstedt, T. (2018) Association mapping of flowering and plant height traits in germplasm enhancement of maize doubled haploid (GEM-DH) lines. *The Plant Genome* 11:170083 11. Type: Journal Articles Status: Published Year Published: 2018 Citation: De la Fuente, G., Frei, U.K., Trampe, B., Nettleton, D., L?bberstedt, T. (2018) A diallel analysis of a maize donor population response to in vivo maternal haploid induction. I: Inducibility. *Crop Sci.* 58:1830-1837

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responsible for the high success rate of obtaining DH lines without colchicine. Field and sweet corn, gametophytic incompatibility: To minimize the possibility of GMO contamination, we are developing pollen excluding varieties of corn using a natural pollen exclusion (PE) process called gametophytic incompatibility (GI). We continued to advance sweet corn breeding populations for the purpose of developing pollen excluding sweet corn lines. These lines contain the Ga2 GI locus known to exclude pollen of non-Ga2 varieties, including GMO varieties. This year we carried out tests for PE ability and will advance those plants that display the ability. The extent of PE systems in maize germplasm is poorly understood, making it difficult to plan deployment of these systems. In an effort to better understand the distribution of the three known pollen exclusion systems, we also carried out tests for the ability of sweet corn inbreds to overcome the PE barriers Ga1, Ga2 and Tcb-1. Sweet corn lines were crossed to plants known to possess each of the three PE barriers. In the unlikely event that such crosses do produce kernels, we will characterize PE ability of these sweet corn lines in more detail. Objective 2 We produced hybrid seed to distribute to farmers for observation of two high-yielding hybrids, and produced seed of six experimental hybrids produced from DH parents with high levels of methionine. We produced test cross seed of 22 promising hybrids for evaluation next year and carried out one organic yield trial containing 32 hybrids. This activity will allow our farmer-cooperators to evaluate the products of this grant and to provide feedback to the researchers, ensuring that grant activities are relevant to the needs of our customers. Objective 3 Field plot design and data collection of 2019 farmer trials were finalized at the MOSES conference 2019. The 2019 season was challenging. Cold and wet weather delayed planting by two to three weeks; July's rainfall was 80% below normal; and harvests have been delayed due to wet weather. The trial at ISU Neely-Kinyon Farm in Greenfield, Iowa, was not planted until June 12, where five USDA lines were compared. Emergence was depressed due to the wet weather, averaging 70% in the 5769 and 8517 lines, and significantly lower, at 56%, in the other lines. Yields and grain quality have not yet been calculated from this site due to wet weather delaying harvest. The second set of trials was conducted on three farms-two in Iowa (field corn) and Minnesota (sweet corn). The Minnesota farm suffered from a wet spring and only 50% of the sweet corn plants produced ears. The White Earth Nation 4-H students, who helped maintain the plots, reported high kernel sweetness. The field corn sites, while enduring excessive rains early and late in the season, fared well in 2019. Mid-July commercial organic variety plant height was equivalent across the two on-farm sites, averaging 158 cm. Weed management was more difficult in 2019. Grass weeds averaged 16 weeds/sq. meter across all sites. Broadleaf weeds averaged 5 weeds/sq. meter. The breeder's corn could not be planted on-farm this year, due to the NC site experiencing excessive rains for an entire month. Stalk nitrate samples were collected from two on-farm sites and analyzed by a commercial lab. Stalk nitrate content, which ranged from 345 ppm at the NW farm to 1,331 ppm at the NE farm, demonstrated the lack of nitrate pollution potential usually experienced with conventional corn production. Ear samples were hand-collected from each variety at physiological maturity at two of the three sites and dried to 15% moisture. Corn ear weight averaged 200 g/ear for Blue River 57A30 compared to 218 g/ear for Viking 5014. Kernel weight per ear averaged 168 g for Blue River 57A30 compared to 198 g/ear for Viking 5014. To date, none of the on-farm field corn trials has been machine-harvested for yields because of wet weather. After harvest, we will determine grain quality from ear samples from all sites. Objective 4 The "Organic Plant Breeding" course has been approved by the CALS curriculum committee. A proposal for the "Organic Plant Breeding" certificate program has been developed and approved by the Department of Agronomy curriculum committee and faculty. Next step is approval by the CALS curriculum committee. Once approved, the Certificate program can be offered, as three courses are already available, while the "Organic Plant Breeding" course (as last course in the program) would be developed. \*\*PUBLICATIONS (not previously reported):\*\* 2018/09 TO 2019/08 1. Type: Journal Articles Status: Published Year Published: 2018 Citation: Khamphan, P., Lomthaisong, K., Harakotr, B., Ketthaisong, D., Willcox, M., Scott, M.P., Lertrat, K., Suriham, B. 2018. Genotypic variation in anthocyanins, phenolic compounds and antioxidant activity in cob and husk of purple field corn. *Agronomy Journal*. 8(11):271. <https://doi.org/10.3390/agronomy8110271>. 2. Type: Journal Articles Status: Published Year Published: 2018 Citation: Duangpapeng, P., Ketthaisong, D., Lomthaisong, K., Lertra, K., Willcox, M., Scott, M.P. 2018. Corn tassel: A new source of phytochemicals and antioxidants for value-added products in agro-industry. *Agronomy Journal*. 8:242. <http://dx.doi.org/10.20944/preprints201809.0517.v1>. 3. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Delate, K., T. Lubberstedt, P. Scott, W. Tracy and R. Turnbull. 2019. Developing field and sweet corn hybrids for organic producers: The ACES project. ASA Annual Meeting, San Antonio, TX. <https://scisoc.confex.com/scisoc/2019am/meetingapp.cgi/Paper/120078>. 4. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Boerman, N., Frei, U.K., and T. Lubberstedt. 2019. Characterization of Spontaneous Haploid Genome Doubling in Maize. ASA Annual Meeting, San Antonio, TX. <https://scisoc.confex.com/scisoc/2019am/meetingapp.cgi/Paper/118480>. 5. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: On-Farm Organic Corn Trials Farmer-Cooperator Meeting, Midwest Organic and Sustainable Education Service (MOSES) Organic Conference, La Crosse, WI, 2/23/19 6. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Organic Research in Iowa - Horticulture Dept., University of Florida, Gainesville, FL, 3/20/19 7. Type: Conference Papers and Presentations Status: Published Year Published: 2019

Citation: ♦Organic Research Update ♦ OREI ACES Project♦ ♦ ISU Neely-Kinyon Farm Field Day, Greenfield, IA, 8/20/19, K. Delate and Paul Scott 8. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: ♦Iowa Organic Research Update♦ ♦ Oregon State University, Corvallis, OR, 10/24/19 9. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Delate, K. 2019. ♦Organic Field Day Planned at Neely-Kinyon Farm,♦ ISU Extension and Outreach, Ames, IA: July 31, 2019: <https://www.extension.iastate.edu/news/organic-field-day-planned-neely-kinyon-research-farm> 10. Type: Journal Articles Status: Published Year Published: 2018 Citation: Sanchez, D., Liu, S., Ibrahim, R., Blanco, M., Lübberstedt, T. (2018) Association mapping of seedling root traits in exotic derived doubled haploid lines of maize. *Plant Science* 268:30-38 11. Type: Journal Articles Status: Published Year Published: 2019 Citation: Andorf, C., Beavis, W.D., Hufford, M., Smith, S., Suza, W., Wang, K., Woodhouse, M., Yu, J., Lübberstedt, T. (2019) Technological advances in maize breeding: Past, present and future. *Theor. Appl. Genet.* 132: 817-849 12. Type: Journal Articles Status: Published Year Published: 2019 Citation: Yang, J., Li, H., Qu, Y., Chen, Q., Tang, J., Lübberstedt, T., Liu, Z. (2019) Identification of QTL for haploid male fertility in maize (*Zea mays* L.). *Plant Breeding* 138: 259-265 13. Type: Journal Articles Status: Published Year Published: 2019 Citation: Vanous, A., Blanco, M., Martin-Schwarze, A., Flint-Garcia, S., Bohn, M., Edwards, J., Lübberstedt, T., Gardner, C. (2019) Stability analysis of kernel quality traits in exotic derived maize doubled haploid lines. *The Plant Genome* 12(1):1-14 14. Type: Journal Articles Status: Published Year Published: 2019 Citation: Vanous, K., Jubery, T.Z., Ganapathysubramanian, B., Lübberstedt, T. (2019) A scalable reusable framework for early discrimination of maize haploids. *The Plant Phenotype Journal* 2:1 DOI: 10.2135/tppj2018.10.0008

2019/09 TO 2020/08 What was accomplished under these goals? Overall impact statement: The overall goal of the project is to substantially increase the productivity of organic field and sweet corn production within organic crop rotations, by improving the efficiency of breeding through doubled haploid (DH) technology and traditional breeding methods, focused on early plant vigor and competitiveness factors. Another goal is to develop a Certificate program in Organic Plant Breeding, which can be accessed online in the U.S. and internationally. All project partners conducted field experiments for evaluation of maize lines under organic conditions, and / or breeding work to develop novel germplasm. For example, 400 lines developed for this project were evaluated in six environments. Superior lines with regard to agronomic performance under organic conditions and for quality traits were identified. These superior lines will receive by conventional crosses additional properties which will make future breeding of organic maize varieties more efficient. A major finding was that an important property for DH technology is simple inherited (one single major gene), which will simplify breeding strategies to incorporate this property into elite breeding materials. Our findings will lead to changes in knowledge and action in the way breeding of organic field and sweet corn will be done in future, by using DH technology and the novel genetic property characterized in this project. Outcomes will be first generation field and sweet corn lines carrying this property along with another important trait (cross-incompatibility) employed in this project. Stakeholders will be engaged to evaluate first prototypes under organic practice conditions, to determine robustness of this materials. The certificate program on Organic Plant Breeding to be established in this program will be a venue, to share new knowledge in the field or organic plant breeding with students, working professionals, and others engaged in this topic. Strengthened organic plant breeding will lead to better adapted and more competitive varieties under organic conditions, which benefits farmers but also the general public, as this should impact prices of organic products. Objective 1: Develop novel organic field corn and sweet corn genotypes for the commercialization pipeline that utilize more efficient methods of breeding. Field corn, BS39-derived lines: From the tropical BS39 population that was adapted by Dr. Hallauer (ISU) to Iowa conditions, more than 400 inbred lines were derived by the single seed descent (SSD) or doubled haploid (DH) approach, the latter using either colchicine for genome doubling, or a colchicine-free genetic mechanism for spontaneous haploid genome doubling (SHGD). Testcrosses of the best 50 lines were evaluated under organic conditions in two locations (Ames, Iowa and Arlington, Wisconsin) in 2019, and in 2020 (Madison). Despite of COVID-19 and a derecho that impacted Iowa, both 2020 trials were successfully completed, data analysis pending. In addition, a 2nd cycle breeding approach was adopted: the best two lines in terms of agronomic performance carrying the spontaneous haploid genome doubling (SHGD) ability were crossed with the 10 best lines with 100% BS39 background in summer 2019. Winter 2019/20, the haploids were induced for these crosses, and spontaneous doubling haploids selected summer 2020. More than 75 2nd generation inbreds with SHGD ability and 75% BS39 genome background were obtained, seed will be multiplied winter 2020/21, and respective inbreds be evaluated within this project during summer of 2021. Introduction of SHGD and Ga1 into field and sweet corn (ISU): Development of donor lines in field and sweet corn carrying Ga1 and the major QTL for SHGD by marker-assisted backcrossing is proceeding as planned, and will be available by end of this project. In Iowa and Wisconsin, sweet corn lines carrying the pollen exclusion locus Ga2 are being developed. These lines have been shown to exclude foreign pollen, making them well suited to organic production systems where foreign pollen can carry GMOs that eliminate the value added by organic production. In Iowa the derecho provided an opportunity for strong selection for stalk lodging. We learned that some of the germplasm developed for this program has moderate resistance to the emerging

pest Fall Army Worm, providing plant breeders with a new resource to combat this pest. In addition, we proposed a molecular model to explain the function of the pollen exclusion systems we are using in this research. This model will help breeders develop effective deployment strategies for pollen exclusion systems. Objective 2: Select and test on-farm genotypes that meet the critical needs of organic producers. Seed production efforts were limited by the pandemic this year. We produced seed of one hybrid for distribution to farmers. Objective 3: Practice technology transfer through a network with organic farmers and organic seed companies. Field plot design and data collection plans for the 2020 on-farm corn variety trials finalized at a project farmer meeting at the MOSES conference on February 29, 2020. The 2020 season on four farms in Iowa (NE, NC, SW, NW) was very challenging, with wet weather in the spring, drought in July and August, and an inland hurricane (derecho) with 100 mph winds on August 10, that seriously affected the NC on-farm sites in Jefferson, Iowa. Plant emergence was excellent in 2020, with no statistical differences in plant populations among the commercial organic field corn varieties (BR 57A30, BR 48G35, Viking 0.18-06 UP and Viking 51-04), ranging from 30,438 plants/acre at the NE site to 38,250 plants/acre at the SW site. Late-July commercial organic variety plant height varied across varieties and sites, with the Viking 51-04 averaging 248 cm across three sites, compared to the 190-cm height in the BR48G35 at the NC site. Weed populations were well managed in 2020 across all sites. Grass weeds mid-June ranged from 2 weeds/sq. meter at the SW site, to 21 weeds/sq. meter at the NE site. Broadleaf weeds averaged 1 weed/sq. meter at the NE site to 5 weeds/sq. meter at the SW site. Correlations between weed populations and yields will be conducted after all plots are harvested. The USDA-bred corn (19SMPS/19SJWF and 19SFWE/185MPS) was only grown at the NC site, where there were with no statistical differences in plant populations, averaging 33,500 plants/acre. Late-July 19SMPS/19SJWF plant height averaged 157 cm while 19SFWE/185MPS averaged 182 cm. Weed populations were very low at this site, with mid-June grass weeds averaging 4 weeds/sq. meter and broadleaf weeds averaging 1 weed/sq. meter. Corn stalk nitrate samples collected from on-farm sites were analyzed by a commercial lab. Stalk nitrate content ranged from 218 ppm in the Viking 18-06 variety to 1,667 ppm in the BR57A30 variety. Ear samples were hand-collected from each variety at physiological maturity and measured for various parameters. Corn ear weight ranged from 101 g/ear for the BR48G35 variety at the NW site to 273 g/ear for Viking 18-06 at the NE site. Kernel weight per ear ranged from 88.2 g/ear for the BR48G35 variety at the NW site to 238 g for Viking 18-06 at the NE site. Kernel weight in the USDA varieties ranged from 175 to 192 g/ear, with ear length ranging from 18 to 19 cm. As in previous years, with the BR 57A30 producing the greatest yield in 2019, at 233 bu/acre, at the NW site. Objective 4: Develop a graduate Certificate program in Organic Plant Breeding. The Certificate program "Breeding for Organic Crops" have been approved by ISU and will be offered from 2021 on, as three courses are already available, while the "Organic Plant Breeding" course (as last course in the program) will be developed in 2021. A student in the Distance MS program at ISU (Christy Montes) developed materials in her creative component (defense 11/2020), which will be used in the organic plant breeding course. \*\*PUBLICATIONS (not previously reported):\*\* 2019/09 TO 2020/08 1. Type: Journal Articles Status: Published Year Published: 2020 Citation: Coffman, S.M., Hufford, M., Andorf, C., Lübberstedt, T. (2020) Diversity of haplotype structure among commercial maize ex-PVP lines in relation to key pre-commercial germplasm. *Theor. Appl. Genet.* 133:547-561 <https://doi.org/10.1007/s00122-019-03486-y> 2. Type: Journal Articles Status: Published Year Published: 2020 Citation: Ren, J., Boerman, N., Liu, R., Frei, U.K., Trampe, B., Vanous, K., Chen, S., Lübberstedt, T. (2020) QTL mapping of spontaneous haploid genome doubling. *Plant Sci.* 293:110337 <https://doi.org/10.1016/j.plantsci.2019.110337> 3. Type: Journal Articles Status: Published Year Published: 2020 Citation: Trampe, B., Goncalves, I., Frei, U.K., Ren, J., Chen, S., Lübberstedt, T. (2020) QTL mapping of Spontaneous Haploid Genome Doubling using Genotype by Sequencing Approach in maize. *Theor. Appl. Genet.* 133:2131-2140 <https://doi.org/10.1007/s00122-020-03585-1> 4. Type: Journal Articles Status: Published Year Published: 2020 Citation: Gustin, J.L., Frei, U.K., Baier, J., Armstrong, P., Lübberstedt, T., Settles, A.M. (2020) Maize haploid classification using Single Kernel Near-Infrared Spectroscopy. *Plant Breeding (in press)* DOI: 10.1111/pbr.12857 5. Type: Journal Articles Status: Published Year Published: 2020 Citation: Abel, C. A., Coates, B. S., Millard, M., Williams, W. P. & Scott, M. P. Evaluation of XL370A-Derived Maize Germplasm for Resistance to Leaf Feeding by Fall Armyworm. *Southwest. Entomol.* 45, 69-74 (2020). 6. Type: Journal Articles Status: Published Year Published: 2020 Citation: Ma, L., Qing, C., Frei, U.K., Shen, Y., Lübberstedt, T. (2020) Association mapping for root system architecture traits under different nitrogen conditions in germplasm enhancement of maize doubled haploid (GEM-DH) lines. *The Crop J* 8:213-226 <https://doi.org/10.1016/j.cj.2019.11.004> 7. Type: Journal Articles Status: Published Year Published: 2020 Citation: Boerman, N.A., Frei, U.K., Lübberstedt, T. (2020) Impact of Spontaneous Haploid Genome Doubling in Maize Breeding. *Plants* 9: 369 8. Type: Journal Articles Status: Published Year Published: 2020 Citation: Trentin, H.U., Frei, U.K., Lübberstedt, T. (2020) Maternal haploid inducer development in maize. *Plants* 9: 614 [doi:10.3390/plants9050614](https://doi.org/10.3390/plants9050614) 9. Type: Journal Articles Status: Published Year Published: 2020 Citation: Qu, Y., Wu, P., Ren, J., Liu, Z., Tang, J., Lübberstedt, T., Chen, S., Li, H. (2020) Mapping of QTL for kernel abortion caused by in vivo haploid induction in maize (*Zea mays* L.). *PLoS One* 15: e0228411 10. Type: Journal Articles Status: Published Year Published: 2020 Citation: De la Fuente, G., Frei, U.K., Trampe, B., Ren, J., Bohn, M.O.,

Yana, N., Verzeznazzi, A., Murray, S.C., Lübberstedt, T. (2020) A diallel analysis of a maize donor population response to in vivo maternal haploid induction. II: Spontaneous Haploid Genome Doubling. *Crop Sci.* 60: 873-882 DOI: 10.1002/csc2.20021 11. Type: Journal Articles Status: Published Year Published: 2020 Citation: Costa Almeida, V., Trentin, H.U., Frei, U.K., Lübberstedt, T. (2020) Genomic prediction in maternal haploid induction in maize. *The Plant Genome* 13:e20014 DOI: 10.1002/tpg2.20014 12. Type: Journal Articles Status: Published Year Published: 2020 Citation: Lu, Y., Moran Lauter, A. N., Makkena, S., Scott, M. P. & Evans, M. M. S. Insights into the molecular control of cross-incompatibility in *Zea mays*. *Plant Reprod.* (2020) doi:10.1007/s00497-020-00394-w. 13. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Bapat, Amruta R, Moran Lauter, AN, Hufford, MB, Scott, MP. 2020. Insights into the genetic architecture of the *ga1* locus in maize genotypes. *Maize Genetics Conference Abstracts* 62:P122. <https://www.maizegdb.org/data-center/reference?id=3230341> 14. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Delate, K. (2020) ♦ On-Farm Organic Corn Trials ♦ ♦ Farmer-Cooperator Meeting, Midwest Organic and Sustainable Education Service (MOSES) Organic Conference, La Crosse, WI, 2/29/20 15. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Delate, K. (2020) ♦ Organic Research in Iowa ♦ - Horticulture Dept., University of Florida, Gainesville, FL, 3/18/20 (via Zoom) 16. Type: Journal Articles Status: Published Year Published: 2019 Citation: Delate, K., T. Lübberstedt, P. Scott, W. Tracy and R. Turnbull. 2019. Developing field and sweet corn hybrids for organic producers: The ACES project. ASA Annual Meeting, San Antonio, TX. <https://scisoc.confex.com/scisoc/2019am/meetingapp.cgi/Paper/120078> 17. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Delate, K. 2019. Developing field and sweet corn hybrids for organic producers: The ACES project. ASA Annual Meeting, San Antonio, TX. Presented Nov. 11, 2019. 18. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Delate, K. 2020. Video: Virtual Neely-Kinyon Farm Organic Field Day. Available at: <https://www.youtube.com/watch?v=P PpIV5EmT4> 19. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Delate, K. 2020. Virtual Organic Field Day Available On-Line. ISU Extension and Outreach, September 11, 2020. Available at: <https://www.extension.iastate.edu/news/virtual-organic-field-day-video-availabl e-online> 20. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Delate, K. 2020. Organic Agriculture Concerns Amid COVID-19. ISU Extension and Outreach, May 5, 2020. Available at: <https://www.extension.iastate.edu/news/organic-agriculture-production-concerns- amid-covid-19> 21. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: McCluskey, C. W.F.Tracy, Midwest Organic and Sustainable Education Services (MOSES) Organic Farming Conference Research Poster Session, La Crosse, WI, Midwest Corn Growers' Perceptions and Management Strategies of On-Farm Genetic Diversity. 22. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: McCluskey, C. W.F. Tracy Selections (ACES) Organic Breeding Program: Novel Strategies to Develop Field & Sweet Corn for Organic Producers (Proceedings at <https://seedalliance.org/publications/proceedings-from-the-10th-organic-seed-gr owers-conference/>) 23. Type: Theses/Dissertations Status: Published Year Published: 2020 Citation: McCluskey, C. Master of Science in Agroecology at the University of Wisconsin-Madison, Corn in the Upper Midwest Farmers' Perceptions and Strategies for Managing On-Farm Genetic Diversity \*\* \*\*

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# Improving the Prevention, Management and Treatment of Lameness on Organic Dairy Farms

<b>Accession No.</b>	1013162
<b>Project No.</b>	IOWVPIu2017-02481
<b>Agency</b>	NIFA IOWVA
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26852
<b>Proposal No.</b>	2017-02481
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2021
<b>Grant Amount</b>	\$1,919,465
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Plummer, P. J.
<b>Performing Institution</b>	IOWA STATE UNIVERSITY, S. AND 16TH ELWOOD, AMES, IOWA 50011

## NON-TECHNICAL SUMMARY

Bovine lameness is a leading animal welfare concern and surpasses mastitis as the most costly clinical disease of dairy cattle. Despite the clear connection of lameness to welfare and profitability, there are very few resources available to organic producers interested in improving their prevention, management, or treatment of lameness. This project directly addresses two of the 2016 OREI Priorities, specifically the priority associated with advanced on-farm research to experimentation (RFA priority 1) and the priority related to the development and demonstration of educational tools for cooperative extension personnel (RFA priority 2). The goal of this proposal is to develop, validate and disseminate protocols, specific to organic dairy production systems and management, which aid organic producers in making management and treatment decisions related to lameness. The central hypothesis of the research portion of this integrated proposal is that the unique management practices on organic dairy farms necessitate a systematic evaluation of organic system specific risk factors and interventions. In the extension portion of the project the goal is to disseminate this information to the stakeholders and then to help them apply the information to their operation. The rationale that underlies the proposed research is that an understanding of organic specific lameness risk factors and treatment protocols will lead to improved recognition, prevention and management of lameness on organic dairies. The research proposed in this application is significant, because dissemination and application of the knowledge gained improves the economic sustainability of organic dairy farms while clearly benefiting the welfare of the cattle.

## OBJECTIVES

The goal of this proposal is to develop, validate, and disseminate protocols specific to organic dairy production systems and management, which aid organic producers in making management and treatment decisions related to lameness. The central hypothesis of the research portion of this integrated proposal is that the unique management practices on organic dairy farms necessitate a systematic evaluation of organic system specific risk factors and interventions. In the extension portion of the project, the goal is to disseminate this information to the stakeholders and then to help them apply the information to their operation. The rationale for this project is that significant differences in management practices limit the translation of data derived from lameness studies on non-organic operations and necessitate a systematic evaluation of organic system specific risk factors for the development of lameness. The research proposed in this application is significant because dissemination and

application of the knowledge gained is expected to improve the economic sustainability of organic dairy farms while clearly benefiting the welfare of the cattle. In order to address this critical need and accomplish the goal of this proposal, we have developed three objectives outlined below. Objective 1: Determine the prevalence of lameness on organic dairy operations across multiple regions of the US while evaluating the herd level management practices that are unique to organic production and are associated with either an increased or decreased risk of lameness. The hypothesis for this aim is that organic specific management practices, such as distance walked to graze, presence or absence of laneway improvements, trace mineral status, and regular footbath use, will be risk factors that impact lameness incidence and prevalence. Objective 2: Utilize evidence-based medicine principles to determine the most effective strategies that can be employed by organic dairy operations to manage and treat the leading causes of lameness. The hypotheses for this aim is that direct side-by-side comparison of the efficacy of organically acceptable products for managing and treating bovine lameness will identify specific products that provide better outcomes, and that implementation of these therapies prevention/control and treatment protocols will reduce the incidence and prevalence, respectively, of lameness in organic dairy cattle. Objective 3: Adapt the highly successful "Master Hoof Care" extension and outreach program to provide organic specific education modules that incorporate knowledge acquired through the prior aims with proven extension outreach methods. The goal of this aim is to modify a well-established extension program related to lameness in order to provide the specific educational and training needs of the organic dairy community.

## APPROACH

Objective 1: Determine the incidence and prevalence of lameness on organic dairy operations across multiple regions of the US while evaluating for herd level management practices that are unique to organic production and are associated with either an increased or decreased risk of lameness. Introduction: One of the areas of interest repeatedly raised by our stakeholder panel was the need to better understand which management practices are associated with an increased or decreased risk of lameness on organic dairies. In the words of Dr. Guy Jodarski, veterinarian for Organic Valley's 1,600-plus organic dairies, "There is a huge diversity of farms and systems within the organic dairy sector. There's a real need to do a wide-ranging survey of many different organic dairies for incidence and causes of lameness. The factors causing lameness and how it is managed should be documented. Identification of significant risk factors for lameness should be compiled and used to reveal management strategies that successfully prevent lameness for cows in organic dairy herds. Then we need to document management differences between the top 25% and bottom 25% of organic dairy herds for lameness and provide education for all organic dairy managers on the factors the top 25% (least lameness) employ and what the deficiencies are in the bottom 25% (most lameness)." Objective 1 is designed to address this need by evaluating the management practices employed by 100 organic dairies located throughout the United States while simultaneously evaluating the lameness incidence and prevalence within the herd. We will then utilize epidemiological methods to determine which risk factors for lameness exist in organic dairies, and to identify those factors that reduce the duration of lameness when it occurs. As an added benefit, and perhaps equally as useful, we will derive data that allows organic operations to benchmark themselves against their peers with regard to lameness in their herd. This benchmarking encourages farmers that are doing well to keep up what they are doing while encouraging those that are in the lower percentiles to work hard to catch up with their peers. Ultimately, this works to improve cattle welfare and health as statistics and metrics shift upwards (continuous improvement is encouraged). Finally, in this objective we will also evaluate the ability of organic dairy operators to identify lame animals (prevalent cases) that need attention. Hypotheses: The hypotheses for this objective is that organic specific management practices such as distance walked to graze, presence or absence of laneway improvements, trace mineral status, and regular footbath use will be risk factors that impact lameness prevalence. Objective 1.1 Evaluate farm management practices and lameness incidence and prevalence on 100 organic dairies located across the United States to determine which management practices impact farm-level prevalence of lameness. Objective 1.2 Provide regional and national benchmarking data for use by organic dairy producers to better understand their lameness prevalence. Objective 1.3 Evaluate the producer preferences and perceptions of treatment efficacy for various causes of lameness in organic dairy operations. Objective 1.4 Determine which cause of lameness is most prevalent on organic dairies in order to prioritize training, management, biosecurity, and educational efforts. Objective 2: Utilize evidence-based medicine principles to determine the most effective strategies that can be employed by organic dairy operations to manage and treat the leading causes of lameness. Introduction: Our stakeholder advisory panel also expressed the desire for having data available regarding treatment efficacy on commonly used organic therapies. Dr. Hubert Karreman, organic veterinarian and author of several organic veterinary textbooks, summarized this sentiment as follows, "How well does copper sulfate really work? How well does betadine and sugar really work? And what role does mineral nutrition play specific to hoof health?" The principles of evidence-based medicine would suggest that the most powerful way to determine the best treatment option is through a prospective randomized clinical trial. In this type

of trial, different treatments or preventative measures are compared side-by-side in a randomized fashion with a defined treatment outcome (in this case, resolution of the disease). In this objective, we propose to evaluate the most widely utilized lameness treatments (based on the results from Objective 1.4) in one of several such experiments. Hypothesis: The hypothesis for this objective is that direct side-by-side comparison of the efficacy of organically acceptable products for managing and treating bovine lameness via prospective randomized clinical trials will identify specific products that provide better treatment outcomes and improved welfare for organic dairy cattle.

**Objective 2.1** Determine the most effective organic approved therapy for treatment of digital dermatitis in organic dairy systems. **Objective 2.2** Determine the most effective organic approved therapy for treatment of footrot in organic dairy systems. **Objective 2.3** Determine the most effective organic approved therapy for treatment of sole ulcers in organic dairy systems. **Objective 2.4** Determine the effect of trace mineral supplementation on the incidence of lameness in an organic dairy. **Objective 3:** Modify the highly successful "Master Hoof Care" extension and outreach program to provide organic specific modules that incorporate knowledge acquired through the prior aims with proven extension outreach methods.

**Introduction:** Input from our stakeholder advisory panel suggested that there is a significant need for readily available resources related to identification and classification of lesions associated with lameness, routine and corrective foot trimming, prevention of lameness, and treatment of lameness on organic dairy operations. While there are unique aspects of organic dairy management that need to be addressed, much of the basics of lesion identification and foot trimming are essentially identical to the process used in conventional dairy systems. The co-PD, Dr. Jan Shearer, is the developer of the Master Hoof Care Technician (MHCT) extension program. This program has been in use for over 20 years, has won several USDA extension awards, and has been used in over 20 different countries. We will utilize the MHCT as the foundation of this objective, with the addition of a significant number of organic specific modules appropriate for organic producers. **Goal:** The goal of this objective is to modify a well-established extension program related to lameness to meet the educational and training needs of the organic dairy community.

**Objective 3.1:** Development of organic specific training materials using the Master Hoof Care Technician program as a foundation. **Objective 3.2:** Delivery of organic specific educational programs to organic dairy producers. **Objective 3.3** Evaluation of the extension training efforts using the Kirkpatrick Four Level Training Evaluation Model. **\*\*Progress\*\*** 09/01/17 to 08/31/22 **\*\*Outputs\*\*** Target Audience: The target audience for this period was two-fold. First, we continued to stay in contact with the almost 75 organic producers enrolled on the project, despite not being able to visit due to covid. Additionally, enrollment of cattle in the prospective clinical trial continued on one farm. The second audience was the broader organic community that we interacted with both through organic cooperatives and digitally. **Changes/Problems:** The significant issue we faced that required us to change the research plan was the emergence of a global pandemic in 2020 and continuing through the end of the funding period. This completely shut down travel and increased concern among farmers on having outside visitors to their facilities. As a result we had to cancel the second visits to farms and migrate the extension training to online, however the producers and stakeholders adapted well and still found the outcomes beneficial. **What opportunities for training and professional development has the project provided?** Training of the graduate student and hoof trimmers involved in the organic prospective trial occurred throughout the trial. The farm visits are offering new one-on-one training opportunities for the farmers to review their lameness lesion identification and locomotion scoring expertise. **How have the results been disseminated to communities of interest?** We have presented abstracts at three national conferences. In addition we have provided updates to the organic community through the Organic Valley field staff. **What do you plan to do during the next reporting period to accomplish the goals?** Nothing Reported **\*\*Impacts\*\*** **What was accomplished under these goals?** During the period of the grant we completed the majority of the goals, with the exception of having some changes due to covid pandemic.

**Objective 1:** During this project we made first evaluations of 74 farm visits in the northeast, midwest and southeast portions of the US. These farms were identified with the assistance of Organic Valley with eligibility including that the farms were certified organic, shipping milk at the time of the visit and milking 20 or more cows. In each region organic valley identified a sampling frame and we worked with their field staff to finalize farms willing to participate. While we had 25 visits to the northwest planned and had planned to do repeat visits to the first 74 farms, these were all canceled due to travel bans put in place by our institution due to Covid. Having to drop these second visits impacted our ability to evaluate change on the farms as a result of our training, however we are still able to provide benchmarking and aggregate data on practices related to lameness in the organic production system. That data has been summarized in a manuscript that is under review. **Objective 2:** Despite travel bans, enrollment in the prospective randomized clinical trials continued for all 4 studies, including digital dermatitis, footrot, white line disease and sole ulcers. This was possible since the farm staff are the ones that actually collect this data, so travel on our part was not necessary. We enrolled 1166 cows. Given that each cow has 5 rechecks this amounts to roughly 5300 cow evaluations performed. The outcome of these four prospective clinical trials are currently under review for publication. **Objective 3:** This objective had the most significant negative impact due to the travel ban. We were able to continue some training in the early part of the project but pretty much everything came to a stop in March of 2020. As an alternative we developed a web based training modules for the Organic Master Hoofcare Training Program. **\*\*Publications\*\*** - Type: Journal Articles

Status: Under Review Year Published: 2023 Citation: DESCRIBING HERD MANAGEMENT STRATEGIES OF CERTIFIED ORGANIC DAIRY FARMS IN THE UNITED STATES AND DETERMINING RISK FACTORS ASSOCIATED WITH LAMENESS. - Type: Journal Articles Status: Under Review Year Published: 2023 Citation: EVALUATING THE EFFECTIVENESS OF USDA ORGANIC ALLOWABLE TREATMENTS ON THE MANAGEMENT AND TREATMENT OF DIGITAL DERMATITIS IN DAIRY CATTLE - Type: Journal Articles Status: Under Review Year Published: 2023 Citation: EVALUATING THE EFFECTIVENESS OF USDA ORGANIC ALLOWABLE TREATMENTS ON THE MANAGEMENT AND TREATMENT OF SOLE ULCERS IN DAIRY CATTLE \*\*Progress\*\* 09/01/20 to 08/31/21 \*\*Outputs\*\* Target Audience: The target audience for this period was two-fold. First, we continued to stay in contact with the almost 75 organic producers enrolled on the project, despite not being able to visit due to covid. Additionally, enrollment of cattle in the prospective clinical trial continued on one farm. The second audience was the broader organic community that we interacted with both through organic cooperatives and digitally. Changes/Problems: The major issue is the continued pandemic. We have transitioned from the in-person extension training to the development of digital on-demand training to partially address this issue. With regard to farm visits we have no alternative options at this time and simply need to wait for the pandemic to slow. What opportunities for training and professional development has the project provided? We have continued to train the graduate student in the scientific method, manuscript and poster writing and scientific publications. How have the results been disseminated to communities of interest? We have presented abstracts at three national conferences. In addition we have provided updates to the organic community through the Organic Valley field staff. What do you plan to do during the next reporting period to accomplish the goals? Depending on the pandemic situation we hope to get back to doing field visits for objective 1, however travel is still not allowed for us and the farms are not willing to host us at the present time. We also plan to complete the prospective randomized clinical trials and publish the online training materials for the Master Organic Hoof Care Program. \*\*Impacts\*\* What was accomplished under these goals? Due to the continuing covid pandemic we have remained unable to conduct on-farm visits as part of objective 1. We hope to be able to return to those in 2022. However, we have been able to continue the prospective randomized clinical trials at the one dairy. We have completed the first digital dermatitis trial and have commenced a second trial testing the "winner" of the first trial against three additional organic therapies. Enrollments in the foot rot trial, white line disease trial and sole ulcers trials are nearing completion. In addition, since in-person extension meetings are not a viable option in the pandemic we have converted our approach to developing web based video modules for the Master Organic Hoof Care program. We anticipate these being completed next year and available online. \*\*Publications\*\* - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Krebill C, Shearer J, Scott HM, Bothe H, Umase S, Sanabria I, Iza E, Baron J, Hernandez R, Plummer PJ. Evaluating the effectiveness of organic therapies on treatment and management of bovine digital dermatitis. Conference for Research Workers in Animal Disease, December 5-8, 2020 - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Krebill C, Shearer J, Scott HM, Bothe H, Umase S, Sanabria I, Iza E, Baron J, Hernandez R, Plummer PJ. Comparing the efficacy of antibiotic alternatives for the management of contagious digital dermatitis in dairy cattle. NIAMRRE Knowledge Exchange Virtual Poster Event, July 30-31, 2020 - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Krebill C, Shearer J, Scott HM, Bothe H, Umase S, Sanabria I, Iza E, Baron J, Hernandez R, Plummer PJ. Comparing the efficacy of antibiotic alternatives for the management of contagious digital dermatitis in dairy cattle. Midwest AMR Consortium Virtual Poster Event May 26-29, 2020

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## Integrated Research and Extension Planning - Organic Swine

<b>Accession No.</b>	1013012
<b>Project No.</b>	MIN-02-G03
<b>Agency</b>	NIFA MIN\
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26817
<b>Proposal No.</b>	2017-02440
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2018
<b>Grant Amount</b>	\$50,000
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Li, Y.; Heins, BR, J.; Martin, WA, .; Johnston, LE, .

### NON-TECHNICAL SUMMARY

This planning project will lead to establishment of the first organic swine program at a land grant university with an ultimate goal of improving sustainable organic swine production. Specific objectives are to: 1) Identify key issues in organic pork production that will be addressed in research plans; 2) Seek collaboration with scientists and farmers to develop an integrated OREI proposal; 3) Explore the current alternative swine facility at the WCROC for organic swine research. The following critical areas will be addressed: 1) Benefits and benchmarking of different organic swine production systems by including biological and economic efficiency, product quality, animal welfare, carbon footprint, and impact on soil and water; 2) Alternatives to antibiotics to treat organic pigs that become ill; 3) Alternative feed ingredients for organic pigs; 4) Systems-based best management practices for organic pig production in the Midwestern. The outreach objectives are: 1) To provide research-based information to end-users; 2) Provide opportunities for organic swine producers to share experiences; 3) Provide forums for producers, certification agencies, meat processors, consumers, and the general public. To achieve these objectives, a multi-disciplinary planning team and three focus groups will be formed. Through seminars, farm and research site visits, meetings of focus groups and the planning team, research areas will be identified, and research and extension plans will be developed. Based on the research and extension plans, an integrated OREI proposal will be developed for submission, and an organic swine program will be established at the University of Minnesota.

### OBJECTIVES

Our long-term goal is to improve and sustain organic swine production by providing research-based technical support. To achieve the long-term goal, this project will bring scientists from multiple disciplines, farmers and their stakeholders together to create research and extension plans for an organic swine program at the University of Minnesota. Based on these research plans, an integrated OREI proposal will be developed for submission. Specific objectives of this planning project include: 1) identify key issues in organic swine production that will be addressed in research plans, 2) seek collaboration with scientists and farmers to develop an integrated OREI proposal, and 3) explore the alternative swine facility at the WCROC for organic swine research and production. Throughout the planning process, the following critical areas will be addressed: 1) benefits and benchmarking of different organic swine production systems (seasonal vs. continuous; pasture vs. outdoor access) by including biological and economic efficiency, product quality, animal welfare, carbon footprint, and impact on soil and water; 2) alternatives to antibiotics that maintain health of organic pigs; 3) alternative feed ingredients for organic pigs; and 4) systems-based best management practices for organic swine production in

the Midwest. The outreach objectives will be to provide research-based information to organic swine producers, field agents, veterinarians, extension educators, Ag professionals, consumers, and the general public. We will also provide opportunities for organic swine producers to share their experiences and lessons learned with each other and with potential organic swine producers.

## APPROACH

Methods to achieve the objectives include organic pig farm visits, seminar series, focus group meetings and discussions, and planning team meetings. The purposes of farm visits are to identify: 1) Pros and cons of current organic swine facilities which will be used in exploring the organic swine facility at the WCROC; 2) Key issues in productivity, profitability, animal health and welfare, which will be used in development of research plans; and 3) Opportunities for collaboration. Five organic pig farms and institutes will be visited by PD and Co-PDs. The objectives for the seminar series are to: 1) educate the planning team, focus groups, organic swine producers, students, and other participants about organic pig production; 2) identify research areas for development of research plans; and 3) evaluate benefits and benchmarking of different organic swine production systems. Five seminars, followed by open discussions will be organized either at the WCROC or St Paul campus. Each seminar will address one of the following themes: costs and returns of organic pig production, and market demands for organic pork; diversity of organic swine production systems and management strategies; breeds and genotypes for organic pig production; alternatives to antibiotics and alternative feed for organic pigs; animal health, animal welfare, and environmental impact of organic pig production. The goal of the focus groups will be to identify key issues in expanding and sustaining organic pig production. Three focus groups will be formed, including a producer group, a stakeholder group (certifiers, meat processors, and marketers), and a scientist group. Each group will meet at least once with at least three of the planning team members present at each meeting. Meetings for producers and stakeholders will be held in southeast Minnesota close to participants from three states, Minnesota, Iowa, and Wisconsin. Meetings for the scientist group will be held on the St Paul campus. Meeting minutes will be used in development of research and extension plans. The planning team will meet quarterly during the project period at the WCROC and St Paul campus. The initial meeting will identify speakers for seminars, members for each focus group, meeting agendas, and confirm roles and responsibilities of each team member. The following meetings will summarize input from seminars, focus groups, and farm visits, finalize research areas for both long-term and short-term goals, and develop research plans which will be used in the integrated OREI proposal for submission. **\*\*FINAL REPORT\*\* 09/01/17 to 08/31/19 \*\*Outputs\*\***

**Target Audience:** The target audience of this project is organic (including certified organic, transitioning to organic and potential organic) pig farmers, organic certification agents, organic pork marketers, veterinarians, agricultural professional, extension educators, graduate and undergraduate students, and animal scientists. Outcomes of the project have been delivered to audiences through publications in social media, newspapers, newsletters, University of Minnesota Extension website, presentations at conferences, seminars, workshops, and focus-group meetings, and communications during farm visits.

**Changes/Problems:** Nothing Reported

**What opportunities for training and professional development has the project provided?** This project provided training opportunities for organic farmers, organic certification agents, organic advocates (personnel from organic associations, local food organizations, and farmer market organizations), extension educators and investigators of the project. About 120 participants, including 90 organic pig farmers attended educational events, shared their experiences and were advised at workshops, seminars, focus-group meetings, farm visits and through one-on-one communications. The project also provided opportunities for investigators of the project, a graduate student, and an undergraduate student to visit organic pig farms across four states (MN, IA, WI and PA) to identify issues and learn experiences from farmers in organic pig production. The project strengthened the research team and the research program of organic swine at the University of Minnesota.

**How have the results been disseminated to communities of interest?** Outcomes of the project have been disseminated to organic farmers and their stakeholders, ag professionals, and researchers through presentations at conferences, workshops and seminars; publications through social media and website; and communications with individual farmers through farm visits (see the full list of Products). Selected farmers who were visited by investigators of the project received recommendations for improvement in organic pig production on their farms. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

**\*\*Impacts\*\*** What was accomplished under these goals? In contrast to the rapid development in organic agricultural production, organic pig production in the U.S. remains negligible. Factors that restrict organic swine production include high cost of organic feed, difficulty in management for outdoor access and confinement-free housing systems, parasite control without using synthetic dewormers, and access to organic meat markets. Solving these problems requires research using systematic approaches. This project is the first to establish an organic swine research and extension program at a land grant university in the Midwest where about 50% of organic pork is produced (USDA, 2018). The project has been successfully completed and resulted in the establishment of an organic swine research and extension program at the University of Minnesota. The organic swine program is built upon two research proposals that were generated

from this project and funded by the Organic Transition Program of National Institute of Food and Agriculture, USDA (Award \# 2018-51106-28772; Award \# 2017-51106-27129). The established organic swine program at the University of Minnesota will benefit organic and transitioning pig farmers by providing research-based solutions to issues in organic pig production, benefit meat processors and consumers by quantifying quality of organic pork, and benefit the general public at large through sustainable organic agricultural production.

Accomplishment of Objective 1) identify key issues in organic swine production that will be addressed in research plans: An online survey was conducted to collect information regarding organic pig production and key issues in the Midwest. The survey was sent to 120 individuals through UMN Alternative Swine Listserv, and 15 individuals (13%) responded to the survey. Four face-to-face focus group meetings with farmers and their stakeholders were organized to discuss issues in organic pig production. The focus-group meetings were held at four locations across the region to reach local farmers: St Cloud, MN (8 participants on Jan 11th, 2018); in La Crosse, WI (25 participants on Feb. 23rd, 2018); in Rochester, MN (18 participants on April 12th, 2018); and in Morris, MN (13 participants on June 20th). Five organic pig farms in four states (Minnesota, Wisconsin, Michigan, and Pennsylvania) were visited by the PI and investigators of the project to collect information on challenges in organic pig production. Identified key issues in organic pig production are summarized into four categories: 1) Animal Health (parasites, diarrhea, essential oil or other ways to treat sick animals); 2) Production Costs and Efficiency (feed, bedding, and start-up costs, returns on investment, piglet pre-weaning mortality); 3) Supplies and Markets (lack of organic feed and protein sources, and feed mills, slaughter/meat processing plants and markets for organic pork); 4) Organic Standards and Research (reality of organic standards, difficulty to access pastures year-round in the Midwest, lack of research funds to solve production issues). Potential research topics suggested by the focus groups were: 1) Development of tools for organic pig production, such as vaccination programs, deworm programs, and organic feeding programs; 2) Development of management strategies for raising pigs on pastures, such as parasite control, formula and feed additives for pastured pigs, effective and efficient ways of fencing, pasture management through animal and crop rotation; 3) To investigate individual variation in immunity, growth performance, and parasite resistance; 4) To identify best genetics/breeds for organic pig production; 5) To evaluate nutritional and economic value of alternative feed ingredients for organic pigs; 6) Biosecurity in organic pig production. Farmer participants expressed strong support of this project, and were enthusiastic about collaborating with universities in future organic pig research.

Accomplishment of Objective 2) seek collaboration with scientists and farmers to develop an integrated OREI proposal: The project provided opportunities for the PI and investigators to interact with organic pig farmers and researchers across the country. Through individual interactions with interested audience at focus-group meetings, seminars and farm visits, collaborators from the Rodale Institute in Kutztown, Pennsylvania were identified. An integrated research and extension proposal was developed and submitted to the Organic Transition Program of NIFA in 2018, with three researchers from the Rodale Institute and one researcher from the Kutztown University as key collaborators. The proposal addresses parasite control on organic pig farms which was one of the key issues identified in Objective 1 of this project. The proposal was fully funded by NIFA (award#: 2018-51106-28772; Title: Manure and pasture management to reduce swine parasites in organic pastured pork production). In addition, another proposal was developed in collaboration with scientists from multi-disciplines in Minnesota to tackle another key issue identified in Objective 1. This proposal focuses on reducing feed cost in organic pig production and was funded by the Organic Transition Program of NIFA (award \# 2017-51106-27129; Title: Breaking barriers to organic swine transition: utilizing cover crops as feed ingredients to reduce feed cost). The two funded research projects demonstrate the successful completion of Objective 2.

Accomplishment of Objective 3) explore the alternative swine facility at the WCROC for organic swine research and production: We have collected information on what works and what does not work in housing systems for organic pigs during farm visits. The information is used to develop a design of the organic pig housing system at the WCROC for production and research. Currently, pigs are raised under near-organic conditions, and economic environmental impacts of organic pig production are underevaluation. This is a continuing effort beyond the project period. To complete the extension component of this project, four seminars and workshops were organized in St Cloud, MN (27 participants), Rochester, MN (18 participants), Morris, MN (13 participants), and Waterloo, IA (28 participants) for researchers, farmers and stakeholders to discuss best management practices for organic swine production. The seminars and workshops addressed four critical areas: 1) Benefits and benchmarking of organic swine production systems; 2) Strategies to maintain health of organic pigs; 3) Feeding organic pigs with alternative feed ingredients; and 4) Management strategies for diverse organic swine production systems. By using materials presented by the speakers at the seminars and information through literature review, three factsheets were developed and published through the UMN Extension website. These factsheets (1. Highlights - Certified Organic Production in the USA; 2. Improving Health Status of Organic Pigs; 3. Early Detection of Sick Pigs in Organic Production Systems) were designed to address questions and concerns from organic farmers. To demonstrate the best practices of organic pig production, four organic pig farms in Minnesota, Iowa, Wisconsin, and Pennsylvania were filmed. Three video clips will be developed from these films to demonstrate practices of biosecurity, feed management, and pasture management on organic pig farms. \*\*Publications\*\* - Type: Other

Status: Other Year Published: 2019 Citation: Li, Y., L. Johnston, B. Heins, R. Cox, W. Lazarus, J. Tallaksen, W. Martin, F. Forcella, R. Gesch, R. Carr, and A. Hernandez. 2019. Organic Swine Research at the University of Minnesota. Department of Animal Science Showcase, University of Minnesota. St Paul. MN. Apr. 3, 2019. - Type: Websites Status: Published Year Published: 2019 Citation: Li, Y., L. Johnston, B. Heins, J. Tallaksen, W. Lazarus, R. Cox, and W. Martin. 2019. Identifying Challenges in Organic Swine Production. Stevens County Times - Morris Sun Tribune, Mar. 11, 2019. Farm Section Addition 2019. Available at: [https://issuu.com/morrissuntribune/docs/2019\\_farm](https://issuu.com/morrissuntribune/docs/2019_farm) - Type: Websites Status: Published Year Published: 2017 Citation: Features from the Farm: News from the West Central Research and Outreach Center - Organic Swine Production. Stevens County Times - Morris Sun Tribune. Oct. 30, 2017. Available at: <https://www.stevenscountytimes.com/business/4351358-features-farm-news-west-central-research-and-outreach-center>. - Type: Websites Status: Published Year Published: 2017 Citation: Dr. Li Awarded Funding for Organic Swine Production Research. Department of Animal Science, University of Minnesota. Available at: <https://www.ansci.umn.edu/li-organic-swine> - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Li, Y., and A. Hilbrands. 2019. Reducing piglet mortality in loose farrowing systems. Midwest Organic Pig Conference, Waterloo, IA. Mar. 8, 2019.

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# One-two Punch for Organic Poultry Processing: Knocking Out Foodborne Pathogens with Plant Derived Antimicrobials and Farmer Training

<b>Accession No.</b>	1012987
<b>Project No.</b>	MISW-2017-02420
<b>Agency</b>	NIFA MISW
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26815
<b>Proposal No.</b>	2017-02420
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2020
<b>Grant Amount</b>	\$1,998,748
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Donoghue, A. M.; Donoghue, DA, J.; Vukina, TO, .; Fanatico, AN, .; Darre, MI, J.; Venkitanarayanan, KU, .; Gekara, ON, .; Owens, CA, MI.; Pescatore, AN, J.; Kollanoor-Johny, AN, .; Luo, YA, .; Arsi, KO, .; Upadhyay, AB, .; Upadhyaya, IN, .; Martin, WA, .
<b>Performing Institution</b>	USDA-ARS, GENETICS AND PRECISION AGRICULTURE UNIT, 810 HIGHWAY 12 EAST PO BOX 5367, MISSISSIPPI STATE, MISSISSIPPI 39762

## NON-TECHNICAL SUMMARY

Despite a consistent growth in organic poultry production, few research and outreach programs target the needs of these producers. Both conventional and organic poultry products have been identified as major sources of Salmonella and Campylobacter, the two most common food-borne pathogens in the US. Organically raised poultry must have outside access, as required by USDA Organic Standards, which increases bird exposure to these pathogens. However, organic standards allow few methods for reducing these pathogens on poultry products. We work with many organic poultry farmers and their highest priority is research/education associated with processing and post-harvest food safety. Preliminary results from our team indicate that several food-grade, plant-derived antimicrobials are effective in reducing pathogens on poultry and eggs, highlighting the potential to improve safety of organic poultry products. This proposal aims to reduce Salmonella and Campylobacter on poultry meat/eggs using plant-derived antimicrobials applied as wash, spray, fumigation or coating treatment at critical post-harvest control points. Moreover, shelf-life and consumer acceptability of organic poultry products subjected to these interventions will be determined. The outreach/extension objectives of this proposal are to provide food safety/processing workshops for organic poultry producers and disseminate research results of the project to the organic poultry community. Additionally, tools such as eXtension, eOrganic, webinar, and Google Analytics will be utilized to disseminate project results to organic poultry producers. Our proposal seeks to support organic producers through OREI goals 1 and 2, and specifically addresses the priority area (3) regarding improving post-harvest food safety and shelf life of organic products.

## OBJECTIVES

The long-term goal of this proposal integrating research, extension and education is to provide organic poultry producers with natural, effective, and safe strategies for improving the post-harvest microbiological safety and

shelf life of organic poultry products. The specific objectives of the proposed research are to Reduce Salmonella counts on eggs using natural, food-grade plant compounds (eugenol, carvacrol, and  $\beta$ -resorcylic acid) applied as a post-harvest antimicrobial wash, spray, fumigation or coating treatment. Reduce Salmonella and Campylobacter counts on poultry carcasses using plant derived, food-grade compounds (eugenol, carvacrol,  $\beta$ -resorcylic acid) at critical control points in the processing line (scalding and chill tank) or applied as a coating treatment. Determine the quality, shelf life and consumer acceptability of poultry carcasses and eggs subjected to the aforementioned interventions. Benefit-Cost assessment of organic egg/carcass disinfection process and operation. The outreach/extension objectives of this proposal are to: Provide food safety and processing workshops for organic poultry producers. Disseminate research results from this project to the organic poultry community, through conferences, electronic and printed materials, and training activities in a research and teaching oriented organic poultry facility. Conduct outreach to organic poultry producers, avian health professionals, extension specialists and other stakeholder regarding the objectives and results of this project. Measure the impact of extension and education efforts

## APPROACH

**RESEARCH Objective 1.** To reduce Salmonella on eggs using eugenol, carvacrol, and  $\beta$ -resorcylic acid applied as a post-harvest antimicrobial wash, spray, fumigation or coating treatment. Five isolates of *S. Enteritidis* pre-induced for resistance to 50  $\mu$ g/mL of nalidixic acid will be used for the study. The solutions of plant compounds in water will be prepared according to a previously published protocol (Din et al., 2015). Stock solutions of ethanol and lecithin will be separately prepared by dissolving in water at 5% (w/v). To prepare emulsion, 2.5 g of each plant compound will be first pre-mixed with 0.5 mL ethanol (oil phase). The oil phase will then be added to 10 mL of aqueous phase containing 5 mL of lecithin, followed by homogenization at 13,500 rpm for 3 min. The solution will be dried into a powder by spray drying, which could be re-dissolved in water for further use. **Objective 1a.** To test the efficacy of plant compounds as an antimicrobial wash for killing *S. Enteritidis* on shell eggs will be investigated at 32°C (objective 1a). Five eggs will be used per treatment/time point (n=15) and the study will be repeated three times. **Objective 1b:** Batches of 15 inoculated eggs each will be placed in a sterile egg carton and each Salmonella-inoculated egg will be sprayed with 10 mL of sterile deionized water containing 0, 0.5 or 1% eugenol, carvacrol or  $\beta$ -resorcylic acid using a spray bottle. Water containing 200 ppm of chlorine and peracetic acid as spray solution, will be included to simulate industry controls. The eggs will be allowed to dry at 23°C for 2 h. After treatment, each egg will be separately transferred to a sterile WhirlPak™ bag containing 30 mL of neutralizing broth, and will be rubbed by hand for 1 min. *S. Enteritidis* will be enumerated by plating dilutions of the neutralizing broth on XLD+NA and TSA+NA plates. The plates will be incubated at 37°C for 48 h for bacterial enumeration. Moreover, a batch of treated eggs will be refrigerated (to mimic post-harvest storage) in egg cartons for 3 weeks, and surviving Salmonella populations on refrigerated eggs will be determined on days 3, 5, 7, 14 and 21 of storage. **Objective 1c:** The eggs will be placed on sterile wire racks in a temperature-controlled incubator and subjected to fumigation at 23°C or 42°C with 0, 0.5 or 1% carvacrol, eugenol, or  $\beta$ -resorcylic acid for 0, 5, 15 or 30 min using a portable fumigator. After fumigation, Salmonella populations on eggs will be enumerated as mentioned earlier. A batch of fumigated eggs will be refrigerated (to mimic post-harvest storage) in egg cartons for 3 weeks, and Salmonella populations on refrigerated eggs will be determined on days 3, 5, 7, 14 and 21. **Objective 1d:** Inoculation of eggs with *S. Enteritidis* cocktail will be performed as described earlier. Each Salmonella-inoculated egg will be dipped in 10 mL of chitosan coating solution either with or without 0.5 or 1% carvacrol, eugenol, or  $\beta$ -resorcylic acid for 30 sec, followed by drying in laminar hood for 2 h at room temperature. Inoculated, uncoated eggs will serve as control. After coating treatment, the eggs will be refrigerated and Salmonella populations will be enumerated as mentioned earlier on day 0, 1, 3, 5, 7, 14, 21. **Objective 2.** To reduce Salmonella and Campylobacter on chicken carcasses using eugenol, carvacrol, and  $\beta$ -resorcylic acid applied as a post-harvest intervention during processing or applied as an antimicrobial coating treatment. **Objective 2a.** In this study, we will determine the efficacy of plant compounds against Salmonella and Campylobacter when applied as an antimicrobial wash treatment. Whole chicken carcasses will be purchased from specialized stores selling organic poultry and poultry products. Two hundred microliters of a 5-strain mixture of *S. Enteritidis*/C. jejuni in PBS (108 CFU/mL) will be used to spot inoculate the carcass. The inoculum will be spotted (~ 50 spots, 20  $\mu$ L each) evenly on the surface, and air-dried for 30 min at 23°C to facilitate bacterial attachment. The plant compounds will be prepared as described under objective 1. Batches of 5 carcasses will be submerged in 20 L of sterile water (with or without plant compounds) maintained at 4°C in a plastic tub for a period of 30 min or until the carcass temperature reaches 4°C to mimic the FDA-recommended chill tank treatment. After treatment, carcasses will be sampled at 0, 1, 3, 5, and 7 days of refrigerated storage to determine surviving Campylobacter and Salmonella counts. Five carcasses (n = 5) will be used per treatment/time point and the study will be repeated twice. The above experimental template will be used to test plant compound efficacy in scald tanks. In this case, the treatments will be applied at a temperature of 60°C for 1 min. Birds used for these experiments will be electric stunned and bled prior to use in the experiments. Sample

size, treatments, sampling points, and replications will be same as described for the chill tank studies. Objective 2b. In this study, we will determine the efficacy of plant compounds against Salmonella and Campylobacter when applied as a coating treatment. Inoculation of meat with S. Enteritidis/Campylobacter cocktail will be performed as described in objective 2a. Each Salmonella/Campylobacter-inoculated whole carcass will be dipped in 4 L of chitosan coating solution either with or without 0.5 or 1% eugenol, carvacrol and  $\beta$ -resorcylic acid for 30 sec followed by drying in a laminar hood for 2 h at room temperature. Inoculated, uncoated carcasses will serve as control. After coating treatment, the carcasses will be refrigerated and Salmonella/Campylobacter populations will be enumerated on days 0, 1, 3, 5, and 7 days of storage as before. Objective 3. Determine the quality, shelf-life and consumer acceptability of chicken and eggs subjected to the aforementioned interventions. Quantitative quality and sensory testing will be conducted only on products from treatments that have shown to be effective for reducing pathogens. Trained sensory panels will be used to assess consumer acceptability and intensity of overall impression, flavor, juiciness and tenderness of meat. For eggs, consumer triangle tests will be used to determine if consumers can detect a difference between the control eggs and the eggs subjected to the post-harvest treatments. Objective 4: Benefit: Cost assessment of organic egg and carcass disinfection process and operation. The proposed methodology for conducting the benefit-cost analysis will rely on the standard enterprise budgeting techniques. The standard approach for estimating economic benefits (revenue side) is to look at the change in prices consumers would be willing to pay for the new or improved product or service. In this context, the potential economic benefits would materialize if consumers' willingness to pay for this additional organic quality attribute would increase as the result of their perception that new organic products are either safer (healthier) to eat. In this project, however, we will focus only on the cost side of the profit equation, whereas the imputed values for total revenue will be calculated based on the break-even price, which implicitly assumes the zero-profit condition. EXTENSION/OUTREACH We will develop a multi-faceted outreach plan to help organic poultry producers and processors implement science-based and validated approaches at critical control points in the post-harvest processing steps for improving the safety and quality of organic poultry meat and eggs. The project results and educational information will be disseminated to organic processors by a strategic team comprised of experienced poultry outreach specialists and stakeholders, who have been involved in organic poultry production. \*\*Progress\*\* 09/01/17 to 08/31/22 \*\*Outputs\*\* Target Audience: We will target four major stakeholders: poultry scientific community interested in organic poultry, educators in sustainable agriculture, large-scale organic poultry production, and small-scale organic poultry production. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? The project provided training and education to postdoctoral fellows, graduate students and undergraduate students. The post-docs and the students were provided with opportunities to participate in workshops, trainings and professional development activities. Since the beginning of the project, 9 post-docs, 8 graduate students and several undergraduate students were trained and resulted in three dissertations so far. Co-PI Dr. Fanatico along with the farm staff at the Appalachian State University (ASU) developed training components and provide outreach on mobile processing units (MPU) for on-farm poultry slaughter and handling poultry products to maintain high food safety for poultry products and eggs. The Department of Sustainable Development at Appalachian State University (ASU) has a working farm and conducts research on humane on-farm poultry processing with organic food safety practices. We also conduct outreach and offer poultry slaughter training, using a mobile processing unit (MPU). We teach processing on an annual basis and also partner with local farmers. Some use our MPU in educational collaborations with us. We also partner with cooperative extension. MPUs are key to community processing because the equipment can be shared. At ASU, we previously converted our MPU rental program to an educational program and additional upgrades were made to the MPU for food safety. The MPUs at ASU have been used for various educational activities including, backyard poultry producer training in Creston, NC by the North Carolina Cooperative Extension. See <https://watauga.ces.ncsu.edu/2018/09/chicken-processing-workshop/>. Co-PIs at ASU also designed food safety additions to the MPU, developed a sanitation program using natural materials for on-farm processing and updated on-farm poultry processing Standard Operating Procedures (SOPs) for small diversified farms. The Appalachian State University Sustainable Development department held an educational event with Against the Grain (ATG) farm, which used the mobile processing unit to process holiday turkeys. Co-PI, Dr. Fanatico worked with 4 farm workers on food safety topics and trained 10 students in on-farm turkey processing. ASU also hosted a poultry processing workshop with the assistance of Cornerstone Poultry Ventures (see <https://watauga.ces.ncsu.edu/event/52334552/onfarm-poultry-slaughter-workshop/>). A workshop was organized for extension agents and small commercial growers and 11 people were trained. Co-PIs at ASU also designed an outdoor processing set up for the MPU at the SD Farm to demonstrate low-cost practices that manage efficient processing, food safety, animal welfare, and waste management. We have included a focus on waste management for small-scale poultry processing on-farm. Dr. Gekara, Co-PI from Cal Poly, Pomona, made farm visits to nearby poultry farms (small and medium size on free range) and made contacts via one-on-one meetings, online and telephone conversations to answer technical questions regarding nutrition, health management, and questions on safe handling of eggs before marketing to the public. At Cal Poly Pomona, this project supported

one graduate student (MS) and 3 undergraduates (2 were accepted to veterinary school, the third one will be graduating with the plan to pursue MS degree in poultry science. In spite of the restrictions on travel and related COVID-19 pandemic, Co-PIs at Cal Poly attended professional meetings and made farm visits to nearby organic poultry producers, after partial lifting of the quarantine that had been in place since 2018. One of the farms visited in California has a relatively large operation complete with feed mill and egg processing operation. This farm has since established direct links with the college/department at Cal Poly, Pomona and is helping with kick-starting an organic poultry operation (once all regulations as per USDA guidelines are addressed). Co-PIs at Cal Poly organized a presentation by the production manager from the local layer chicken operation who addressed 35 animal science and agricultural science students enrolled at Cal Poly Pomona, 5 of the students are veterans of foreign wars. How have the results been disseminated to communities of interest? We have been working to develop a multi-faceted outreach plan for helping organic poultry producers and processors to implement science-based management strategies to improve the microbiological safety of organic chicken products. Information on poultry production in general, was disseminated to the organic and sustainable agriculture communities by an extension team comprised of experience poultry specialists and stakeholders who have been involved in organic poultry production. Our team has addressed common food safety issues on small, diversified farms during trainings and workshops. We established contacts with local farmers and answered their questions regarding nutrition, health, management, and safe handling of poultry products during our on-farm visits and/or over phone. Also, results from our research were disseminated to poultry producers through direct email contacts, small flock seminars and regional meetings. During this period of the project we have participated at multiple meetings and presented our research findings at scientific conferences, symposiums and webinars. Below is the list of presentations and webinars given by our team as part of the outreach/education activities: "Phytochemicals reduce *Campylobacter jejuni* biofilms on common food contact surfaces" by Dr. Donoghue at the *Campylobacter, Helicobacter* and Related Organisms (CHRO), Belfast UK. 2019 "Alternative approaches against *Salmonella* in poultry" by Dr. Kollanoor Johny at the USDA Food Safety Summit at the University of Minnesota, June 18, 2019 - attended by 200 members who were from USDA, academia, industry, and extension. "Recent research on safeguarding meat supply from drug-resistant *Salmonella*"; by Dr. Johny at the National Research Center on Meat, in Hyderabad, India on August 19, 2019 PI, Dr. Donoghue was invited by Maple Leaf Farms Inc., to present our research at the Annual Duck Conference, 2019 and collaborative efforts are underway to extend the research to duck production. Dr. Donoghue was also an Invited Speaker and gave presentations on: "Alternatives to Antimicrobials and Interventions for Food Safety"; Broiler Summit for poultry industry stakeholders ARS, USDA Feb, Virtual. 2021 Research update, National Poultry Research Center Science and Sundry Seminar Series Sept., Virtual. 2021 "Use of phytochemicals for improving poultry product safety"; by Dr. Johny at the 13th ANECA Poultry Processing Conference in Queretaro, Mexico. A webinar on "Antibiotic Alternatives for Controlling Foodborne Pathogens in Poultry"; by Dr. Arsi (June 9, 2020) as part of the USDA ARS AMR/ATA webinar series. An online seminar on "Current Scenario of Zoonotic Diseases and their Impact on Human and Animal Health"; by Dr. Johny at the 2020 Virtual International seminar organized by the Department of Public Health and Epidemiology, Veterinary College and Research Institute, Tamil Nadu, India. The meeting was attended by a group of 50-75 people including the Dean, Director of the center, Department Head, professors, scientists, research associates and veterinary students. Dr. Johny was an invited speaker at the 2021 South Dakota University - USDA Des Moines District Food Summit meeting on August 4. He discussed the research finding from the project titled, "Exploring Sustainable Alternatives for Poultry Food Safety." An online seminar by Dr. Johny at the 2021 Virtual International seminar on the Relevance of veterinary profession during COVID-19 pandemic conducted by the Indian Veterinary Association, Mannuthy, Kerala, India. Dr. Johny provided a brief background of his research activities as a part of the talk. The meeting was attended or viewed live on Facebook by a group of 300 people that includes the Dean, Department Heads, professors, scientists, research associates and Students from Veterinary College. Presentation on "Structural and functional analyses of the enteric nervous system in animal models of gut neuropathies"; by Dr. Caputi at the graduate program in Cell and Molecular Biology on 23 April, 2021. Presentation on "Exploring the crosstalk between the gut microbiota and the enteric nervous system in animal models of gut-brain axis dysfunctions"; by Dr. Caputi at the Biological Sciences Spring Seminar series, University of Arkansas on 29 April, 2021. Webinar on "Alternatives to Antibiotics and interventions for Food safety"; by Dr. Arsi (27 September, 2021) at the US-Singapore Third Country Training program on Antimicrobial resistance. The participants are all from South East Asian countries and are involved in AMR policy with in their countries. We have participated at meetings frequently attended by organic poultry producers and processors. Dr. Kollanoor Johny, Co-PI at University of Minnesota gave invited presentations at the 2020 and 2022 Midwest Poultry Federation Convention (Minneapolis, MN), one of the largest poultry trade show and convention in the United States, and is a common platform for the industry, academic, and government agencies to discuss various issues in poultry. We published manuscripts in peer reviewed journals and presented our findings at several national and international conferences. Dr. Donoghue also traveled to the University of Perugia, Italy to meet with Dr. Cesare Castellini, visited several organic poultry farms and numerous contacts were made as part of this visit with scientists working in food safety,

sustainable production and health related programs and several excellent leads were made for planned collaborative research. In addition to the aforementioned activities, the following webinars were held on eXtension ([www.eXtension.org/poultry](http://www.eXtension.org/poultry)) by our team during the project period. Essential oils: What are they and why use them in poultry? by Dr. Johny (November 10, 2017), available at: <https://www.youtube.com/watch?v=0nPRFI2-Hgo&feature=youtu.be> So far, the video has received 670 views. Staying healthy with a backyard flock (January 21, 2020) How to perform a simple necropsy (February 19, 2020) Poultry-human bond (March 10, 2020) Raising pullet chicks for egg production in a small or backyard flock (April 14, 2020) Common poultry diseases (May 5, 2020) Slaughter and Processing of Poultry by Dr. Fanatico (June 16, 2020), available at: <https://connect.extension.org/event/butchering-poultry>- 917 views of the recording to date Sanitation and Antimicrobials in Organic Poultry Processing: On-Farm MPU Focus,\" as part of eXtension webinar on Slaughter and Processing of Poultry June 16, 2020. Available at: <https://connect.extension.org/event/butchering-poultry>. Managing egg-laying hens in small and backyard flocks (July 15, 2020) Managing predators with a small and backyard poultry flock (August 4, 2020) Using chick embryology as a teaching tool (August 11, 2020) Raising exhibition chickens (September 1, 2020) Raising your own meat chickens (October 6, 2020) Selecting, handling and cooing turkey (November 4, 2020) Managing multi-species poultry flock (January 5, 2021) Raising ducks for meat production (February 2, 2021) Are heavy metals a concern for backyard and free-range poultry flocks? (March 2, 2021) Raising Coturnix quail for egg production (April 6, 2021) Raising quail for meat production or release (May 4, 2021) Raising ducks for egg production (July 6, 2021) Backyard flock home remedies - What you should and should not do (June 1, 2021) - 370 views of the recording to date Backyard poultry: To vaccinate or not? (Aug 10, 2021) - 844 views of the recordings to date Controlling internal parasites of poultry (May 3, 2022) - 474 views of the recording to date Biosecurity for small and backyard poultry flocks (Jun 2022) - 261 views of the recording to date External parasites of poultry (Jul 7, 2022) - 213 views of the recording to date What do you plan to do during the next reporting period to accomplish the goals? We plan on completing the ongoing studies and publish the outcomes of our research in peer-reviewed journals. Studies to determine the quality, shelf-life and consumer acceptability of chicken and eggs subjected to the proposed interventions will be continued. We developed an online course on &#39;Poultry medicine for veterinarians&#39; (scheduled to start September 2022) Our team will continue to disseminate the results through presentations at scientific conferences, meetings and webinars. We will also explore the potential of sharing the information in eXtension.org in the form of a webinar/workshop. We also scheduled an eXtension webinar on &#39;Knocking out foodborne pathogens with plant derived antimicrobials&#39; for early next year. **\*\*Impacts\*\*** What was accomplished under these goals? ARS Fayetteville scientists have led a team of researchers, academics and extension partners in developing a national program for organic poultry producers. The overall objective of this proposal was to integrate research, extension and education and there by to provide organic poultry producers with natural, effective, and safe strategies for improving the post-harvest microbiological safety, shelf life and quality of organic poultry meat and eggs. Results from our research studies indicate that several food-grade, plant-derived antimicrobials are effective in reducing pathogens on poultry and eggs, highlighting the potential to improve safety of organic poultry products. Extensive outreach and education materials regarding the project research results have been disseminated through scientific seminars, webinars, workshops and online platforms. This research on plant phytochemicals provides the organic poultry industry with economical, effective, and control strategies for food borne pathogens. Many of the practices/strategies developed under this project have been adapted by poultry producers. This project has resulted in presentations at multiple national/international conferences; 14 published peer reviewed manuscripts, 3 proceedings papers, and 3 dissertations. In addition, several more manuscripts are under preparation/ internal review for submission to peer reviewed journals. Below are our accomplishments from specific objectives. Objective 1. To reduce Salmonella on eggs using eugenol, carvacrol, and beta-resorcylic acid applied as a post-harvest antimicrobial wash, spray, fumigation or coating treatment. We investigated several GRAS phytochemicals during this grant (eg. caproic acid, caprylic acid, cuminaldehyde, zingerone and linalool) and tested for their efficacy as a pectin-based coating agent in reducing Salmonella Heidelberg on shell eggs. Moreover, the coating agents tested were monitored for their impact on the surface roughness of the egg shell surface using atomic force microscopy. The research was presented at the 2020 Poultry Science Annual meeting and the manuscript was published in *Frontiers in Sustainable Food Systems*. Additionally, other GRAS compounds such as sodium selenite and sodium picolinate were tested as an antimicrobial spray and/or pectin-based coating on shelled eggs in reducing Salmonella Heidelberg (SH) under refrigerated storage. These studies were completed and the manuscript is under preparation Objective 2. To reduce Salmonella and Campylobacter on chicken carcasses using eugenol, carvacrol, and beta-resorcylic acid applied as a post-harvest intervention during processing or applied as an antimicrobial coating treatment. We have conducted several studies to evaluate the plant-based, GRAS (Generally Regarded as Safe) status compounds (eg. carvacrol, cuminaldehyde, beta-resorcylic acid eugenol, trans-cinnamaldehyde, caprylic acid, caproic acid) for their efficacy against foodborne pathogens, Salmonella and Campylobacter, in post-harvest poultry. We have developed several phenotypic assays, cell culture and gene expression analysis protocols for rapid screening of phytochemicals for efficacy against Salmonella and Campylobacter. Using these assays, we have identified plant-derived

antimicrobials with significant anti-microbial efficacy. Our results indicate that these compounds are effective in reducing pathogen colonization in chickens and survival on poultry products. In addition, using proteomic analysis, our team has been successful in delineating the potential mechanism of action of these compounds. These plant phytochemicals can potentially provide the poultry industry (both conventional and organic) with economical and effective strategies for controlling foodborne pathogens. Further, we also evaluated edible coatings such as chitosan, gum Arabic or pectin fortified with phytochemicals. Antimicrobial edible coatings, due to their presence on products, reduces the chance of cross-contamination during storage and handling. Results from these studies demonstrate that edible coatings fortified with phytochemicals consistently reduced Salmonella and *C. jejuni* and modulated several genes critical for survival and virulence of these pathogens on chicken skin and meat. Objective 3. Determine the quality, shelf-life and consumer acceptability of chicken and eggs subjected to the aforementioned interventions. We have conducted multiple studies evaluating the effect of phytochemicals on the shelf life and color of meat when applied as an antimicrobial wash or coating treatments. A study was conducted to evaluate the efficacy of pectin or chitosan coating fortified with EG to reduce *C. jejuni* on chicken wingettes. Incorporation of 0.5, 1 or 2% EG in pectin significantly improved antimicrobial coating efficacy against *C. jejuni*. In addition, the effect of treatments on chicken wingette color and aerobic bacterial counts to account for spoilage bacteria was evaluated and the manuscript was published in Poultry Science journal. Another study was conducted to determine the efficacy of edible coatings (gum Arabic or chitosan coating) fortified with carvacrol were evaluated for their efficacy to reduce *C. jejuni* on chicken wingettes. Results showed that 1% carvacrol, or the combination of either 0.25%, 0.5% or 1% carvacrol with chitosan significantly reduced *C. jejuni* from day 0 through day 7 by up to 2.5 log<sub>10</sub> CFU/sample. In addition, none of the treatment exerted any significant effect on wingette color. This manuscript was published in Frontiers in Microbiology. We also conducted a study evaluating the efficacy of plant-derived compounds, eugenol, carvacrol, and beta-resorcylic acid reduce Salmonella on chicken wings at scalding and chilling conditions. The study revealed that, plant-derived compounds could be effective and safe antimicrobials against Salmonella on poultry products. The experiments with chicken wings have been completed and presented at the 2020 Annual Poultry Science Association conference. We are in the process of completing the follow up sensory studies. Objective 4: Benefit: Cost assessment of organic egg and carcass disinfection process and operation. We conducted a detailed literature review to identify cost-benefit studies or willingness to pay (WTP) studies where the type of the policy or technology evaluated has some similarities with organic poultry processing studied under this project. We identified some degree of similarities with labor safety improvements, fair-trade practices, environmental improvements and sustainability studies. When it comes to methodologies for elicitation of consumer preferences, different types of choice experiments have been used, such as hypothetical or non-hypothetical auction experiments and choice experiment surveys. Finally, we show how under some assumptions, the benefit transfer approach can be used to calibrate the results of a closely related study to approximate perceived benefits of plant derived antimicrobials use in poultry processing. The objective behind the current project period centers around studying the problem of upward scaling of laboratory experiments data and results to commercial size processing plants with the special focus on the cost structure. We are in the process of preparing a working paper that can be distributed to communities of interest. Upon receiving feedback, the working paper will be revised, and another manuscript will be prepared for publication in a peer reviewed journal. \*\*Publications\*\* - Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Arsi, K., A. Upadhyay, A. Woo-Ming, A. M. Donoghue and D. J. Donoghue. 2017. Use of a Chitosan Based Natural Coating Materials to Reduce Spoilage and Pathogenic Bacteria on Poultry Products. MATBIM 2017 4th International Meeting on Material/Bioprocess Interaction, Porto, Portugal. - Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Wagle, B. R., A. Upadhyay, K. Arsi, I. Upadhyaya, S. Shrestha, K. Venkitanarayanan, A. M. Donoghue and D. J. Donoghue. 2017. Phytochemicals reduce biofilm formation and inactivates mature biofilm of *Campylobacter jejuni*. Poultry Science Annual Meeting. 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Plant-derived compounds eugenol, carvacrol, beta-resorcylic acid reduce Salmonella on chicken wings and organic carcasses at scalding and chilling conditions. *Poultry Science* (under preparation). - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Nair, D.V.T., S. Manjankattil, C. Peichel, A. Donoghue, K. Venkitanarayanan, and A. Kollanoor Johny. 2021. Antimicrobial efficacy of a plant-derived compound, carvacrol, against Salmonella Enteritidis on organic chicken carcasses. 2021 Poultry Science Association Annual meeting, July 19-22, 2021 (Virtual meeting). - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: A. Kollanoor Johny. 2021. Exploring sustainable alternatives for poultry food safety. South Dakota State University Des Moines District Food Safety Summit, August 4. \*\*Progress\*\* 09/01/20 to 08/31/21 \*\*Outputs\*\* Target Audience: Target audience include poultry scientific community interested in organic poultry, educators in sustainable agriculture, largescale organic poultry production, and small-scale organic poultry production. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? The project provided training and education to post-docs, graduate and undergraduate students. As part of the collaborative work completed at USDA ARS, Fayetteville and University of Arkansas, this project has provided training to five post-doctoral fellows associated with the project. At University of Minnesota, an undergraduate student was trained to conduct basic bacteriological procedures and trained to prepare coating solutions for use on eggshell surfaces. At University of Connecticut, two graduate students were trained to conduct research activities, write manuscripts and publish in peer-reviewed journals. Also, three undergraduate students were trained in BSL2 activities as part of this grant and were given opportunities to participate in the research activities, equipping them with knowledge on organic processing and the use of essential oils and their ingredients for poultry food safety. At Cal Poly Pomona, this project supported an undergraduate student who will be graduating this semester with the plan to pursue MS degree in poultry science. The Department of Sustainable Development at Appalachian State University (ASU) has a working farm and conducts research on humane on-farm poultry processing with organic food safety practices. We also conduct outreach and offer poultry slaughter training, using a mobile processing unit (MPU). We teach processing on an annual basis and also partner with local farmers. Some use our MPU in educational collaborations with us. We also partner with cooperative extension. MPUs are key to community processing because the equipment can be shared. During this period of the project we have participated at multiple meetings and presented our research findings at scientific conferences, symposiums and webinars. How have the results been disseminated to communities of interest? Co-PI Dr. Darre has provided information to organic producers in New England via the Main Organic Poultry Producers, and Maine NOFA. Also in Connecticut via the CT NOFA. The Country Hen, a large organic egg producer in Massachusetts has implemented the use of plant derived antimicrobials in their program. Information on the use of plant derived antimicrobials to reduce Salmonella has been provided to 85 participants in the National Egg Quality School in 2017, 2018 and 2019. Several of the participants are organic producers and many of these egg producers/processors have implemented alternative egg sanitizing strategies. Organic egg producers who participated in the National Egg Quality School come from all over the United States and are influencers in their local communities. Organic Egg producers in New England have been provided educational information about the use of alternative egg sanitizing products to reduce Salmonella. Before COVID-19 restrictions effected our travel, Co-PI Dr. Gekara made farm visits to nearby organic poultry producers (3). One of the farms visited has a relatively large operation (>50,000 chickens) complete with feed mill and egg processing operation. This farm has since established direct links with our college/department at Cal poly, Pomona and will be helping us kick-start an organic poultry operation (once we address all regulations as per USDA guidelines). Dr. Fanatico gave a presentation on "Sanitation and Antimicrobials in Organic Poultry Processing: On-Farm MPU Focus," as part of eXtension webinar on Slaughter and Processing of Poultry June 16, 2020. <https://connect.extension.org/event/butchering-poultry>. In November 2020, the ASU Sustainable

Development Department held an educational event with Against the Grain (ATG) Farm. ATG used the sustainable development farm MPU at their farm in Zionville, NC to process holiday turkeys (100). They set up the extended frame and installed the tarp. It is important in terms of food safety to work under a covered area. Co-PI Dr. Fanatico also discussed the importance of using a food grade tank for chilling carcasses. Fanatico worked with the farmer Holly Whiteside to increase efficiency. Fanatico worked with 4 farm workers on food safety topics and trained 2 students in on-farm turkey processing. Because processing took place during the pandemic, Fanatico trained fewer students than usual. In addition, two students trained at New Life Farm with local farmer Cory Bryk using his equipment. During Spring 2021, Fanatico designed an outdoor processing set up for the MPU at the SD Farm to demonstrate low-cost practices that manage efficient processing, food safety, animal welfare, and waste management. We have included a focus on waste management for small-scale poultry processing on-farm. A seminar was delivered by Dr. Johny at the 2021 South Dakota University - USDA Des Moines District Food Summit meeting on August 4. He discussed the research finding from the project titled, "Exploring Sustainable Alternatives for Poultry Food Safety." Dr. Johny was an invited speaker at the conference that had several attendees from multiple universities, poultry industry and government agencies. An online seminar was delivered by Dr. Johny at the 2021 Virtual International seminar on the Relevance of veterinary profession during COVID-19 pandemic conducted by the Indian Veterinary Association, Mannuthy, Kerala, India unit and the Kerala Veterinary and Animal Sciences University. Dr. Johny provided a brief background of his research activities with acknowledgment to this Grant as a part of the talk. The meeting was attended or viewed live on Facebook by a group of 300 people that includes the Dean of the Veterinary College, a few Department Heads, professors, scientists, research associates and veterinary students. Dr. Caputi, a post-doc working on the project gave presentations on: "Structural and functional analyses of the enteric nervous system in animal models of gut neuropathies" at the graduate program in Cell and Molecular Biology (CEMB) on 23 April, 2021. <https://us.bbcollab.com/guest/ca829f996ea3444bb344e2858ab2687> "Exploring the crosstalk between the gut microbiota and the enteric nervous system in animal models of gut-brain axis dysfunctions" at the Biological Sciences Spring Seminar series, University of Arkansas on 29 April, 2021. Co-PI Dr. Arsi presented a webinar on Alternatives to Antibiotics and interventions for Food safety (27 September, 2021) at the US-Singapore Third Country Training program on Antimicrobial resistance. The participants are all from South East Asian countries and are involved in AMR policy with in their countries. In addition to the aforementioned activities, the following webinars were held on eXtension by our team during the current reporting period. September 1, 2020 - Raising exhibition chickens October 6, 2020 - Raising your own meat chickens November 4, 2020 - Selecting, handling and cooing turkey January 5, 2021 - Managing multi-species poultry flock February 2, 2021 - Raising ducks for meat production March 2, 2021 - Are heavy metals a concern for backyard and free-range poultry flocks? April 6, 2021 - Raising Coturnix quail for egg production May 4, 2021 - Raising quail for meat production or release June 1, 2021 - Backyard flock remedies - What you should and should not do July 6, 2021 - Raising ducks for egg production August 10, 2021 - Backyard poultry: To vaccinate or not? What do you plan to do during the next reporting period to accomplish the goals? We plan to continue the research activities associated with the proposed objectives. The results and significance of the currently ongoing experiments will be furnished as an addendum to the final report of the grant. As part of benefit-cost analysis, we plan to study the problem of upward scaling of laboratory experiments data and results to commercial size processing plants with the special focus on the cost structure. As part of our outreach objectives, we will provide updated information on Salmonella Control for laying hens and eggs through the National Egg Quality School. We plan on completing the ongoing studies and publish the outcomes of our research in peer-reviewed journals. Our team will continue to disseminate the results through presentations at scientific conferences, meetings and webinars. We will also explore the potential of sharing the information in eXtension.org in the form of a webinar/workshop. **\*\*Impacts\*\***

What was accomplished under these goals? Study 1: Effect of select phytochemicals in reducing Salmonella Heidelberg on chicken eggs. GRAS phytochemicals, Zingerone, and Cuminaldehyde were tested alone or in combination for inhibitory activity against Salmonella Heidelberg (SH). Both Cuminaldehyde and zingerone, alone or in combination were found to be inhibitory against SH-V6FA, with the combination reducing bacterial count by 3.0 log CFU ( $p < 0.05$ ). Currently optimization of these compounds for use as a pectin-based anti-salmonella coating on eggs is underway. An abstract relevant to research activities conducted thus far under this objective was submitted to the editor of the Frontiers journal series on Sustainable Food Systems. The abstract has been accepted for a full article publication and we intend to submit the final manuscript by November 2021. Study 2: Select phytochemicals reduce *Campylobacter jejuni* in postharvest poultry and modulate the virulence attributes of *C. jejuni* We have completed a study that investigated the efficacy of phytochemicals, namely turmeric, curcumin, allyl sulfide, and garlic oil to reduce *Campylobacter jejuni* in postharvest poultry. The mechanism(s) of action were investigated using sub-inhibitory concentration (SIC) in adhesion, quorum sensing, and gene expression analyses. Our results strongly support that the select phytochemicals can significantly reduce *C. jejuni* in poultry meat. The results were published in Frontiers in Microbiology. Study 3: Eugenol modulates *Campylobacter jejuni* proteome and virulence critical for colonization in chickens. This study investigated the effect of eugenol (a generally recognized as safe status phytochemical obtained from clove oil), on the whole cell

proteomic profile of *C. jejuni*. In addition, the effect of eugenol on factors critical for cecal colonization (bacterial motility, attachment to epithelial cells) in chickens were studied using 0.4% agar for a motility assay and cell culture analysis using chicken primary enterocytes isolated from broilers. The effect of eugenol on expression of *C. jejuni* proteome was quantified using LC-MS/MS analysis followed by targeted proteomics and data analysis using Scaffold Proteomic software. The experiment was conducted three times and the samples were run in triplicates. Whole cell proteomic analysis identified more than 600 proteins in *C. jejuni* with many virulent proteins modulated by eugenol. Follow up motility and attachment assays revealed that eugenol was effective in reducing the motility (> 50% reduction) and attachment of *C. jejuni* to primary chicken enterocytes ( $P < 0.05$ ). Overall, these results delineate the prospective mechanism of action of eugenol on *C. jejuni* and the potential of using this phytochemical to control *C. jejuni* colonization in chickens. The studies were completed and the manuscript is ready for submission.

Study 4: Prophylactic supplementation of eugenol nanoemulsion reduces cecal *Campylobacter jejuni* colonization and modulates gut microbiome profile in broiler chickens This study investigated the efficacy of in-water supplementation of a generally recognized as safe compound, eugenol (EG) as nanoemulsion (NE) in reducing *C. jejuni* colonization in broiler chickens. Two separate trials were conducted. In each trial, chicks were supplemented with EG (normal or NE) in drinking water at 0, 0.0625, 0.125 or 0.25% for 14 days ( $n=10$  birds/treatment/trial). Birds in the inoculated group were challenged with a 4-strain mixture of *C. jejuni* on day 7 and cecal samples were collected on day 14 for enumeration of surviving *C. jejuni*. In addition, the effect of EG on the cecal microbiome was investigated. In-water supplementation of 0.125% EG normal reduced *C. jejuni* counts by  $\sim 1.4$  Log CFU/g in both trials. Similarly, the 0.125% EG NE reduced *C. jejuni* colonization by  $\sim 1.5$  and 3.7 Log CFU/g in trials 1 and 2 respectively as compared to controls ( $P < 0.05$ ). No reduction in feed and water consumption or body weight gain was observed with the supplementation of EG at 0.125% or lower doses ( $P > 0.05$ ). Illumina MiSeq based microbiome analysis revealed that administration of EG and EG NE at tested concentrations modulated the cecal microbiome at genus level in both inoculated and not-inoculated groups ( $P < 0.05$ ) without affecting phyla ( $P > 0.05$ ). Results suggest that EG NE could potentially be used to control *C. jejuni* colonization in broiler chickens.

Study 5: Antimicrobial efficacy of a plant-derived compound, carvacrol, against *Salmonella Enteritidis* on organic chicken carcasses. The present study evaluated the antimicrobial effect of a plant-derived phenolic compound, carvacrol, against *Salmonella Enteritidis* (SE) on chicken carcass in simulated chilling conditions. The chicken carcass was inoculated with a cocktail of four SE serovars either higher inoculum ( $10^8$  CFU/carcass) or lower inoculum ( $10^6$  CFU/carcass) and immersed in antimicrobial treatments for 30 min at 4°C. The treatments included in the higher inoculum study were negative control (NC; non-inoculated carcass immersed in water without any treatments), positive control (PC; carcass inoculated with SE and immersed in water without any treatments), chlorine (CL; 200ppm), peracetic acid (PAA; 200ppm) and carvacrol (CR; 1% (v/v). Similar treatments, except CL, were used in the lower inoculum study. After 30 min immersion treatments, the samples were stored at 4°C. SE from the carcass was isolated using rocking motion and surviving SE was determined on days 0 and 3 (higher inoculum) or days 0 and 7 (lower inoculum) on xylose lysine deoxycholate agar plates. Each experiment was repeated at least 6 times ( $N=6$ ) and data were analyzed using one-way ANOVA. For higher inoculum, PAA and CR treatments resulted in 1.9 and 5.4 log CFU/ml reduction of SE on the carcass on day 0 compared to PC ( $P < 0.05$ ), however, CL treatment yielded no significant reduction of SE ( $P > 0.05$ ). In contrast, on day 3, CR resulted in a 1-log CFU/ml reduction of SE whereas PAA maintained 1.2 log CFU/ml SE reduction ( $P < 0.05$ ). For the lower inoculum, consistent SE reductions were obtained with CR and PAA on days 0 and 7. PAA resulted in 4.5 and 4.9 log CFU/ml reductions of SE on meat on days 0 and 7, respectively ( $P < 0.05$ ). Similarly, CR yielded 5.0 and 4.6 log CFU/ml reduction on these days. Additionally, PAA and CR treatments resulted in 5.0 and 3.0 log CFU/ml reduction of SE in treatment water on higher inoculum and lower inoculum studies, respectively ( $P < 0.05$ ). Results of the study indicated that PAA and CR treatments are effective in controlling SE contamination on chicken carcass. The completed experiments with chicken carcasses have been presented at the 2021 PSA annual meeting.

Study 6: Benefit-Cost assessment. We conducted a detailed literature review to identify cost-benefit studies or willingness to pay (WTP) studies where the type of the policy or technology evaluated has some similarities with organic poultry processing studied under this project. We identified some degree of similarities with labor safety improvements, fair-trade practices, environmental improvements and sustainability studies. When it comes to methodologies for elicitation of consumer preferences, different types of choice experiments have been used, such as hypothetical or non-hypothetical auction experiments and choice experiment surveys. Finally, we show how under some assumptions, the benefit transfer approach can be used to calibrate the results of a closely related study to approximate perceived benefits of plant derived antimicrobials use in poultry processing. We are in process of preparing a working paper that can be distributed to communities of interest. Upon receiving feedback, the working paper will be revised, and another manuscript will be prepared for publication in a peer reviewed professional journal.

**Publications** - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Wagle, B. R., Donoghue, A. M., and Jesudhasan, P. R. 2021. Phytochemicals as an alternative to conventional chemicals for controlling *Campylobacter jejuni* in poultry. 2021 Poultry Science Association Annual meeting, July 19-22, 2021 (Virtual meeting) - Type: Conference Papers and Presentations

Status: Published Year Published: 2021 Citation: Nair, D.V.T., Manjankattil, S., Peichel, C., Donoghue, A., Venkitanarayanan, K., and Kollanoor Johny, A. 2021. Antimicrobial efficacy of a plant-derived compound, carvacrol, against Salmonella Enteritidis on organic chicken carcasses. 2021 Poultry Science Association Annual meeting, July 19-22, 2021 (Virtual meeting). - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: S. Manjankattil. 2021. Antimicrobial efficacy of a plant-derived compound, carvacrol, against Salmonella Enteritidis on organic chicken carcasses. 2021 Poultry Science Association Annual meeting, July 19-22, 2021 (Virtual meeting). - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: A. Kollanoor Johny. 2021. Exploring sustainable alternatives for poultry food safety. South Dakota State University Des Moines District Food Safety Summit, August 4. - Type: Other Status: Published Year Published: 2021 Citation: A. Kollanoor Johny. 2021. Outliving the pandemic: Veterinarians to build stronger COVID19/Post-COVID19 local and global communities. Virtual International seminar on the Veterinarian response to the COVID19 crisis organized by the Indian Veterinary Association, Kerala Veterinary and Animal Sciences University, World Veterinary Association and the College of Veterinary and Animal Sciences, Mannuthy, Kerala, India. May 8. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Wagle, B.R., Donoghue, A.M., and Jesudhasan, P.R. 2021. Select Phytochemicals Reduce Campylobacter jejuni in Postharvest Poultry and Modulate the Virulence Attributes of C. jejuni. Frontiers in Microbiology, p.2270. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Manjankattil, S., Nair, D. V.T., Peichel, C., Noll, S., Johnson, T. J., Cox, R. B., Donoghue, A. M., and Kollanoor Johny. A. 2021. Effect of caprylic acid alone or in combination with peracetic acid against multidrug-resistant Salmonella Heidelberg on chicken drumsticks in a soft scalding temperature-time setup. Poultry Science. 100:101421 IF 3.352. <https://doi.org/10.1016/j.psj.2021.101421> - Type: Journal Articles Status: Other Year Published: 2021 Citation: Wagle, B. R., Marasini, D., Arsi, K., Shrestha, S., Donoghue, A. M., Donoghue, D. J., and Upadhyay. A. 2021. Prophylactic Supplementation of Eugenol Nanoemulsion Reduces Cecal Campylobacter jejuni Colonization and Modulates Gut Microbiome Profile in Broiler Chickens. (Under internal review) - Type: Journal Articles Status: Published Year Published: 2020 Citation: Gupta, A., Bansal, M., Wagle, B., Sun, X., Rath, N., Donoghue, A. M., and Upadhyay, A. 2020. Sodium Butyrate Reduces Salmonella Enteritidis Infection of Chicken Enterocytes and Expression of Inflammatory Host Genes in vitro. Frontiers in Microbiology, 11, p.2309. \*\* \*\*

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# Scale-appropriate Strategies: Cover Crop-based No-till Systems for Small Vegetable Farmers

<b>Accession No.</b>	1013032
<b>Project No.</b>	MOLU2017-02428
<b>Agency</b>	NIFA MO.X\
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26810
<b>Proposal No.</b>	2017-02428
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2020
<b>Grant Amount</b>	\$474,141
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Pinero, J. C.; Mersha Ayele, ZE, .; Eaton, TO, E..

## NON-TECHNICAL SUMMARY

Emerging cover crop-based, no-till systems (CCBNTS) offer solutions to many critical management concerns of organic producers. However, adoption of these systems by small and mid-sized producers has been greatly limited by the lack of scale-appropriate equipment and strategies. This project has been designed to develop, through four research objectives, and promote, via extension programming, effective CCBNTS involving frost-killed, spring-terminated, and living mulch systems that could be easily implemented by small producers. The proposed systems will facilitate both transplant-based production and direct-seeded crops. An innovative component of the research proposed is the use of winter-killed tillage radish to manage the transplanting zone in both living mulch and spring terminated systems. For all four research objectives, we will quantify treatment effects on soil health, arthropod communities, weed suppression/weed seed predation, incidence of soil-borne and foliar diseases, and yield of summer squash and beet crops. Analyses will be conducted to determine the economic viability of each system. The multi-faceted extension component for this project has been designed to reach out to stakeholders within and beyond Missouri through field days, targeted workshops, presentations at local, regional, and national growers and professional conferences, farm walks at grower cooperator land, and through printed media and web-based outlets such as eOrganic. Our Extension efforts seek to document short- and mid-term outcomes and impacts. This project addresses several OREI legislatively-defined goals including #1 (Facilitating the development of organic agriculture production), #2 (Evaluating economic benefits), and #6 (On-farm research and development that emphasizes\...innovation for working organic farms).

## OBJECTIVES

The long-term goal of this project is to develop scale-appropriate cover crop-based no-till systems (CCBNTS) for small and mid-scale organic vegetable producers. The small-scale of the majority of organic vegetable producers in Missouri, and the Midwest more broadly, necessitates research that addresses critical management concerns at appropriate scales of production. A 2014 survey of vegetable growers in Missouri, completed by the PD (Piñero, 2014), helped identify the most prevalent critical management concerns of producers. Grower feedback at local and regional conferences such as the Great Plains Growers Conference has revealed high interest in using cover crops to support profitable and resilient crop production. In response to the above, stakeholders, including grower collaborators, the project advisory panel (composed of 10 members including organic vegetable growers), and Justin Keay (Lincoln University graduate student) were engaged to determine the type(s) of

CCBNTS that could be easily implemented and economically feasible for small and mid-scale producers. Advisory Board members have agreed to meet annually to discuss and evaluate outcomes, opportunities, and obstacles. Grower collaborators will be engaged in on-farm trials of these systems on years 2 and 3 of the project. The research/extension team believe that CCBNTS have the potential to address the most prevalent critical management concerns of limited-resource vegetable producers, which include pests (weeds, insect pests, and diseases) (Piñero et al., 2015), and support profitable, sustainable crop production. The outreach objective of this project is to disseminate research-based information on CCBNTS to increase awareness among small- and mid-scale producers and to foster the adoption and implementation of these systems by small and mid-scale producers. We seek to address some of the most important challenges faced by small- and mid-scale organic farmers by investigating, demonstrating, and disseminating information on scale appropriate strategies to facilitate no-till cover crop-based systems for organic vegetable production. Four different cover crop based no-till systems, which are scale appropriate to small organic farms, will be trialed and information on the impacts on our study parameters; weed density, soil health, arthropod diversity, weed seed predation, yield, as well as soil and foliar disease incidence will be gathered and data shared. Additionally, economic analysis will be performed to evaluate inputs, labor and sales value within each production system. Three of the systems to be evaluated are appropriate for vegetable transplant placement, and the fourth is appropriate for direct seeding of vegetable crops. These four systems include two frost killed (FK) cover crop systems, one spring terminated cover crop system, and one living mulch system, thus evaluating a variety of systems to find solutions offering flexibility in the planning of cash crop planting and cover crop establishment tasks for farmers. All transplant based systems are designed to create a persistent residue or living mulch on the majority of the growing bed as well as a smaller area of low residue in the transplanting zone. The controls with which results will be compared are to be both black plastic and bare soil, for the transplant based systems, and bare soil alone for the direct seeded system. Summer squash will be the crop evaluated in the transplant systems and table beets will be the crop evaluated in the direct seeded system. Specific objectives are 1. To evaluate five different spring termination methods for a hairy-vetch and rye bi-culture and the method's effects on soil health, arthropod communities, weed suppression/weed seed predation, incidence of soil-borne and foliar diseases, and yield of summer squash and beet crops (these parameters will be evaluated for all four research objectives). 2. To investigate the use of white clover living mulch system integrated with tillage radish to manage the transplant zone. 3. To compare the level of cover crop degradation in the spring achieved with varying amounts of fall-applied compost applied to the transplant zone. 4. To evaluate frost-killed tillage radish for use in a direct seeded system for spring production of beets. 5. To perform economic analyses assessing the cost of inputs, labor and the value of the cash crop produced in each CCBNTS and the corresponding control(s). 6. To increase awareness and promote adoption of CCBNTS by small farmers by engaging and educating extension personnel and growers with hands-on training and high-quality print and web-based resources.

## APPROACH

Experimental Plan for Objective 1: To evaluate 5 different spring termination methods for a hairy-vetch and rye bi-culture and treatment effects on soil health, arthropod communities, weed suppression / weed seed predation, incidence of soil-borne and foliar diseases, and yield of summer squash and beet crops. Treatments: The following cover crop termination treatments and two controls will be evaluated: (1) crimper rolled, (2) occultation (3) flail mowed, (4) sickle bar mowed, (5) rotary mowed (6) black plastic mulch on tilled soil (control 1) and (7) bare tilled soil (control 2). Each treatment will be replicated four times following a randomized block design. Site Preparation, Fertility, Irrigation management: In early September of 2017, an area will be disked and tilled as necessary to facilitate a seeding bed for cover crops in treatment plots. Each treatment unit will comprise a 20 feet-long raised bed that will be created with a bed hiller/shaper at 48" width. In control plots for summer squash transplant beds, a mixture of hairy vetch and rye will be broadcasted and harrow-incorporated to simulate standard organic grower practices. In treatment plots, hairy vetch and cereal rye will be planted with a push seeder in September (2017) down the length of each bed seeded in alternating rows on 5" centers. The middle 12" of the bed will be reserved for two rows of tillage radishes at approximately 4" in row spacing. The area between the beds will be 72" wide to facilitate tractor mowing and it will be planted with rye and a biennial clover. These bed alleys will be broadcast-seeded and incorporated through harrowing. Bed alleys will be planted in fall of 2017 and mowed the following spring and as needed throughout the growing season of 2018 to reduce competition with the cash crop and allow for ease of foot traffic. The following May (2018), cover crops will be terminated using various methods. Organic pest management, soil health parameters (including the construction of a soil health index), soil fertility, arthropod abundance and diversity, weed species incidence and abundance, weed seed predation disease incidence, and yield are parameters that will be evaluated in this objective. Experimental Plan for Objective 2: To investigate the use of white clover living mulch system integrated with tillage radish to manage the transplant zone. Treatments: (1) White Clover with frost killed tillage radish, (2) White clover alone with strip tillage, (3) black plastic mulch on tilled soil (control 1) (4) and bare tilled soil (control

2). Each treatment will be replicated four times following a randomized block design. Site Preparation, Fertility, and Irrigation management: Research site history, site preparation, timing, and treatment units are the same as described in objective 1. White clover will be planted with rows spaced 4" apart and seeded at a rate of 12 lb. per acre. The middle 12" of the bed will be seeded only with two rows of tillage radish at 6" in-row spacing. The tillage radish will winter kill and the white clover will overwinter. Squash plants will be produced in the greenhouse for field transplanting. After the last threat of frost, the living mulch will be mowed if taller than 20 cm, and squash transplants will be planted. A small furrow will be created down the length of the bed, in the transplant zone, using a push plow. Drip tape and squash plants will be staged in the furrow, and the furrow will be closed using hand tools. Irrigation will be applied as appropriate and living mulch will be kept mowed to a height of 20 cm in order to reduce competition with the cash crop. Compost will be banded down the length of the bed in all replicates. The area between the beds will be managed in the same manner as stated in objective 1. Data recording for soil parameters, arthropods, weed species and seed predation, foliar disease incidence and yield will be evaluated as indicated for objective 1.

Experimental Plan for Objective 3: To compare the level of cover crop degradation in the spring achieved with varying amounts of fall-applied compost applied to the transplant zone. Treatments: (1) Sorghum-sudangrass and cowpea bi-culture and no compost at planting site. (2) Sorghum-sudangrass bi-culture with .5L compost placed at planting site. (3) Sorghum-sudangrass with 1L compost placed at planting site. (4) Sorghum-sudangrass with 2L compost placed at planting site. (5) Black plastic mulch on tilled soil (control 1), and (6) bare tilled soil (control 2). Each treatment will be replicated four times following a randomized block design. Site Preparation, Fertility, Irrigation management: Research site history, site preparation and treatment units are the same as described in objective 1. In late May of 2017 the cover crop bi-culture will be planted with a push seeder and watered, as deemed necessary to support even germination, in light of rainfall patterns present at the time. The cover crop will be mowed once mid-summer to prevent toppling and encourage vigorous shoot and root growth in the sorghum-sudangrass. Both cover crops in the mix will terminate at the first frost event of the fall of 2017. A measuring tape will be laid out down the length of the bed and compost will be applied with a bucket every 24" so as to facilitate correct spacing of summer squash transplants. Squash plants will be produced in the greenhouse for field transplanting. In the spring of 2018, after the threat of any frost, summer squash will be transplanted into transplant sites using hand tools.

Experimental Plan for Objective 4: To evaluate frost-killed tillage radish for use in a direct seeded system for spring production of beets. Treatments: (1) Frost killed tillage radish direct seeded with spring beets, and (2) Frost killed tillage radish alone, tilled and incorporated and then direct seeded with spring beets. Each treatment will be replicated four times following a randomized block design. Site Preparation, Fertility, Irrigation management: Research site history, site preparation, timing and treatment units are the same as described in objective 1. In early September of 2017, the treatment site will be planted with tillage radishes spaced at 19 cm at a rate of 15 lb. per acre using a push seeder. Radishes will frost kill in the early winter. In the spring of 2018 will be planted in rows between the rows of frost killed radish down the length of the growing bed with an in-row spacing of 3 inches. The control for this study will be a tilled bare soil control in which beets will be planted at the same spacing as in the frost-killed, tillage radish system. Soil parameters, arthropods, weed species and seed predation, and foliar disease incidence will be evaluated as indicated for objective 1. Weeds will be managed to simulate grower practice. Data will be analyzed as done for objective 1.

Experimental Plan for Objective 5: Economic analysis. For each experiment, economic data on total costs, gross returns, and net returns will be compared across treatments to determine the economic viability of each production system. The economic analysis will be in the form of an interactive tool, such as a spreadsheet. Developing a tool will enable producers to model the impacts of proposed changes prior to committing resources to them.

Experimental Plan for Objective 6: To increase awareness and promote adoption of CCBNTS by small farmers by engaging and educating extension personnel and growers with hands-on training and high-quality print and web-based resources. A multi-dimensional outreach has been designed to disseminate project results among stakeholders within and beyond Missouri, and our efforts seek to document outcomes and impacts. To increase dissemination of research results and recommendations to a large and diverse group of growers and technical advisors and impact, our Extension partners include University of Missouri Extension, eOrganic, and eXtension.

**Progress** 09/01/17 to 08/31/22 **Outputs** Target Audience: Small- and mid-scale crop producers in Missouri and other areas of the Midwest. This study will introduce innovative and novel research that will be of great interest to the disciplines of agronomy, entomology, horticulture, weed science and plant pathology. The integrated systems approach to addressing the critical management concerns of small farmers is a unique and innovative approach. Changes/Problems: Because of pandemics and all the restrictions imposed for public gatherings, etc., some of the extension/outreach objectives of this project was not accomplished. What opportunities for training and professional development has the project provided? During the life of this project 10 undergraduate students were trained to conduct field experiments, operate small-scale machinery, collect soil samples, perform laboratory analysis of soil for different enzymes. How have the results been disseminated to communities of interest? A virtual seminar/workshop was conducted in "University of Missouri -soil health monthly seminar series" for faculty and farmers interested in adopting no-till cover crop system for growing organic vegetables. Poster presentation at 1890 Research Symposium. Results of the experiments are being shared in e-

organic ([website https://eorganic.info/notillcovercrops](https://eorganic.info/notillcovercrops)) What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **\*\*Impacts\*\*** What was accomplished under these goals? Field experiments were carried out in three consecutive years (2018-2022) and soil samples were collected from 0-15 cm and processed for analysis. Flail mowing significantly enhanced the potentially mineralizable N, available P, and active carbon. Total PLFA analysis showed about 24% increase for flail mowed, 17% for rotary mowed, and 15% for sickle bar mowed termination methods. There was significant increase in active C content which ranged from 38.9% (rotary mowed), 25.4% (sickle mowed), 23.5% (flail mowed), 16.4% for crimper rolled method, and with 2.8% (occultation) respectively. Individual termination methods had varying effect on select enzyme activities. Results indicated that integrating cover crops have the potential to modify soil microbial community structure and increase soil enzyme activities regardless of termination methods and flail mowing appeared to be relatively good method for managing cover crops in terms of soil microbial functionality and fertility.

**\*\*Publications\*\*** - Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: F. Eivazi, M. Dolan- Timpe, W. Doggett, and Jaime Pinero Comparison of Cover Crop Termination Methods for Small-Scale Organic Vegetable Production: Effect on Soil Fertility and Crop Yield. 1890 Biennial Research Symposium Proceedings. - Type: Journal Articles Status: Under Review Year Published: 2022 Citation: Frieda Eivazi, Jaime Pinero, Marianne, Dolan- Timpe, and William Doggett. Comparison of Cover Crop Termination Methods for Small-Scale Organic Vegetable Production: Effect on Soil Fertility and Health. Communications in Soil and Plant Analysis. **\*\*Progress\*\*** 09/01/21 to 08/31/22 **\*\*Outputs\*\*** Target Audience: Small- and mid-scale crop producers in Missouri and other areas of the Midwest. This study will introduce innovative and novel research that will be of great interest to the disciplines of agronomy, entomology, horticulture, weed science and plant pathology. The integrated systems approach to addressing the critical management concerns of small farmers is a unique and innovative approach. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Two undergraduate students were hired to assist with the planting and maintenance of the plots. Students were trained in the field as for operation of certain machinery, etc. Students were trained in the laboratory to perform analysis of enzymes and other soil parameter measurements. How have the results been disseminated to communities of interest? Seminar presentation at the University of Missouri. Poster presentation at the 1890 Biennial Research Symposium, April 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? Experimental plots were laid out in September 2021, and the objectives were repeated according to the proposed treatments of cover crops. Data were collected on summer zucchini plants during summer 2022. Soil samples taken in Fall 2021, and Spring 2022 were processed for microbial community measurements. The activities of enzymes (acid phosphatase, beta glucosidase, arylsulfatase, beta glucosaminidase, dehydrogenase, and phenol oxidase) were measured using proper methods and correlated with nutrient and organic matter accumulation under different cover crop treatments for soil samples. Results indicated that crimper rolled and sickle bar mowed cover crop termination methods as treatments had higher beta glucosidase and dehydrogenase activities. Other enzyme activities showed varying results with treatments. Total PLFA showed highest activity with rotary mowed termination method. All treatments showed much lower weed populations compared with control (soil only, no cover crop). Yield of summer squash for 2022, in general, was lower than two previous years due to higher mean summer temperature and very dry climatic conditions; however, all treatments showed higher yield than control (bare tilled no cover crop). **\*\*Publications\*\*** - Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: F. Eivazi, M. Dolan-Timpe, W. Doggett 2022. Comparison of Cover Crop Termination Methods for Small-Scale Organic Vegetable Production: Effect on Soil Fertility and Crop Yield. 1890 Symposium Proceedings. **\*\*Progress\*\*** 09/01/20 to 08/31/21 **\*\*Outputs\*\*** Target Audience: Small- and mid-scale crop producers in Missouri and other areas of the Midwest. This study will introduce innovative and novel research that will be of great interest to the disciplines of agronomy, entomology, horticulture, weed science and plant pathology. The integrated systems approach to addressing the critical management concerns of small farmers is a unique and innovative approach. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Two undergraduate students were hired to assist with the planting and maintenance of the plots. Students were trained in the laboratory to perform analysis of enzymes and other soil parameter measurements. How have the results been disseminated to communities of interest? A virtual seminar/workshop was conducted in "University of Missouri -soil health monthly seminar series" for faculty and farmer interested in adopting no-till cover crop for growing organic crops. Results of the experiments are being shared in e-organic website <<https://eorganic.info/notillcovercrops>>. What do you plan to do during the next reporting period to accomplish the goals? This project will expire in August 2022. During this period, all soil samples will be analyzed and data will be tabulated for 3 years and statistical analysis will be performed. Manuscripts will be prepared for submission and final report will be submitted to NIFA. **\*\*Impacts\*\*** What was accomplished under these goals? Experimental plots were laid out in September 2020, and the objectives were repeated according to the proposed treatments of cover crops. Data were collected on beets and summer zucchini plants during summer 2021. Soil samples taken in Fall 2020, and Spring 2021 were processed for microbial community measurements. The

activities of enzymes (acid phosphatase, beta glucosidase, arylsulfatase, beta glucosaminadase, dehydrogenase, and phenol oxidase) were measured using proper methods and correlated with nutrient and organic matter accumulation under different cover crop treatments for soil samples from Fall 2020. Results indicated that crimper rolled and sickle bar mowed cover crop termination methods as treatments had higher beta glucosidase and dehydrogenase activities. Other enzyme activities showed varying results with treatments. Total PLFA showed highest activity with rotary mowed termination method. All treatments showed much lower weed populations compared with control. Yield of summer squash for 2021, in general, was lower than two previous years due to higher mean summer temperature; however, all treatments showed higher yield than control (bare tilled no cover crop).

**\*\*Progress 09/01/19 to 08/31/20\*\*** Outputs Target Audience: Small- and mid-scale crop producers in Missouri and other areas of the Midwest. This study will introduce innovative and novel research that will be of great interest to the disciplines of agronomy, entomology, horticulture, weed science and plant pathology. The integrated systems approach to addressing the critical management concerns of small farmers is a unique and innovative approach. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Two undergraduate students were hired to assist with the planting and maintenance of the plots, etc. Also, to train students with use of remote sensing in agricultural production, a small unmanned aerial Drone equipped with multispectral imagery was flown over the plots and the Images obtained were used in GIS and Remote Sensing course. How have the results been disseminated to communities of interest? A seminar/workshop was conducted to farmers/growers interested in adopting no-till cover crop for growing organic crops. Results of the experiments are being shared in e-organic website <https://eorganic.info/notillcovercrops> What do you plan to do during the next reporting period to accomplish the goals? Experiments will be repeated another season and data will be collected. Impacts What was accomplished under these goals? Experimental plots were laid out in September 2019, and the objectives were repeated according to the proposed treatments of cover crops. Data were collected on beets and summer zucchini plants during summer 2020. Soil samples taken in Fall 2019, and Spring 2020 and were processed for microbial community measurements. The activities of enzymes, acid phosphatase, beta glucosidase, arylsulfatase, beta glucosaminadase, dehydrogenase, and phenol oxidase were measured using proper methods and correlated with nutrient and organic matter accumulation under different cover crop treatments. Publications

**\*\*Progress 09/01/18 to 08/31/19\*\*** Outputs Target Audience: Our target audience is small- and mid-scale crop producers in Missouri and other areas of the Midwest. This study will introduce innovative and novel research that will be of great interest to the disciplines of agronomy, entomology, horticulture, weed science and plant pathology. The integrated systems approach to addressing the critical management concerns of small farmers is a unique and innovative approach. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Three undergraduate students were hired to assist with the planting and maintenance of the plots, etc. Also, to train students with use of remote sensing in agricultural production, a small unmanned aerial Drone equipped with multispectral imagery was flown over the plots and the Images obtained were used in GIS and Remote Sensing course. 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 will continue and repeat the experiments and conduct new experiments at Busby farm. Impacts What was accomplished under these goals? This is the second year of the project and we repeated the experiments as outlined in objectives. In September 2018, experimental plots were laid out according to the objectives at Lincoln University's Allen T. Busby farm which is certified for organic farming research. Soil samples were taken from all plots and were analyzed for macro- and micro-nutrient content. To meet the second objective, in September 2018 raised beds were formed in the rototilled section of the field and were planted with using a Gandy drop spreader with various mixture of crop crops including Purple Bounty hairy vetch CV untreated (Albert Lea), Aroostock Rye CV (untreated Albert Lea), Cereal rye OG (Johnnys select seeds), Hairy vetch OG (Johnnys select seeds), and tillage Radish OG (High Mowing Seeds). The N-Dure vetch/peas/bean inoculant used which was purchased from Johnnys select seeds). Alleyways of the raised beds were planted with white New Zealand White clover CV untreated and Oats OG. Alleyways and raised beds were passed over with a cultipacker. At the end of September, the designated part of the field was disced and rototilled and seed was spread with as following: Cereal Rye -150 lbs/acre; Hairy vetch -55 lbs/acre; then site was passed over with a cultipacker. In late April 2019 the cover crop bi-culture was planted with a push seeder and watered, as deemed necessary to support even germination, in light of rainfall patterns present at the time. Both cover crops in the mix were terminated at the first frost event of the fall of 2019. In the May of 2019, summer squash was transplanted into transplant sites using hand tools. During the season weed species incidence and abundance was monitored and recorded. Also, pest and insect species were identified. Mid-June 2019 the beet crop was terminated due fungal infection by Leaf Spot. Starting second week in June, zucchini was harvested 3 times per week and data was taken as for the size and fresh weight for each cover crop treatments. Aerial Drone equipped with multispectral imagery was flown over the plots and the Images obtained

**\*\*Publications\*\***

## PROGRESS

2017/09 TO 2018/08 Target Audience: Our target audience is small- and mid-scale crop producers in Missouri and other areas of the Midwest. This study will introduce innovative and novel research that will be of great interest to the disciplines of agronomy, entomology, horticulture, weed science and plant pathology. The integrated systems approach to addressing the critical management concerns of small farmers is a unique and innovative approach. Changes/Problems: The original Project Director, Dr. Pinero left Lincoln University in April 2018 and request was made for change of PD which delayed the performance of some of the objectives of the project for 2018 summer season. The new PD was approved by NIFA effective July 2018 and there should not be any future problems in conducting experiments. What opportunities for training and professional development has the project provided? Two undergraduate and one graduate students were hired to assist with the planting and maintenance of the plots, etc. Also, to train students with use of remote sensing in agriculture production, a small unmanned aerial Drone equipped with multispectral imagery was flown over the plots and the Images obtained were used in GIS and Remote Sensing course. 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 will continue and repeat the experiments and conduct new experiments at Busby farm.

2019/09 TO 2020/08 Target Audience: Small- and mid-scale crop producers in Missouri and other areas of the Midwest. This study will introduce innovative and novel research that will be of great interest to the disciplines of agronomy, entomology, horticulture, weed science and plant pathology. The integrated systems approach to addressing the critical management concerns of small farmers is a unique and innovative approach. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Two undergraduate students were hired to assist with the planting and maintenance of the plots, etc. Also, to train students with use of remote sensing in agricultural production, a small unmanned aerial Drone equipped with multispectral imagery was flown over the plots and the Images obtained were used in GIS and Remote Sensing course. How have the results been disseminated to communities of interest? A seminar/workshop was conducted to farmers/growers interested in adopting no-till cover crop for growing organic crops. Results of the experiments are being shared in e-organic website <https://eorganic.info/notillcovercrops> What do you plan to do during the next reporting period to accomplish the goals? Experiments will be repeated another season and data will be collected.

## IMPACT

2017/09 TO 2018/08 What was accomplished under these goals? The experimental plots were laid out according to the objectives of the project at Lincoln University's Allen T. Busby farm which is certified for organic farming research. Soil samples were taken from all plots and were analyzed for macro- and micro-nutrient content. The recommendations for application of different amendments received and the plots were treated accordingly with appropriate rates of amendments. In late May of 2017 the cover crop bi-culture was planted with a push seeder and watered, as deemed necessary to support even germination, in light of rainfall patterns present at the time. The cover crop was mowed once mid-summer to prevent toppling and encourage vigorous shoot and root growth in the sorghum-sudangrass. Both cover crops in the mix were terminated at the first frost event of the fall of 2017. A measuring tape will be laid out down the length of the bed and compost will be applied with a bucket every 24" so as to facilitate correct spacing of summer squash transplants. Squash plants produced in the greenhouse for field transplanting. In the spring of 2018, after the threat of any frost, summer squash was transplanted into transplant sites using hand tools. To meet the second objective, in September 2017 raised beds were formed in the rototilled section of the field and were planted with using a Gandy drop spreader with various mixture of crop crops including Purple Bounty hairy vetch CV untreated (albert lea), Aroostock Rye CV ( untreated albert lea), Cereal rye OG (Johnnys select seeds), Hairy vetch OG (Johnnys select seeds), and tillage Radish OG (High Mowing Seeds). the N-Dure vetch/peas/bean inoculant used which was purchased from Johnnys select seeds). Alleyways of the raised beds were planted with white New Zealand White clover CV untreated and Oats OG. Alleyways and raised beds were passed over with a cultipacker. At the end of September, the designated part of the field was disced, and rototilled and seed was spread with a Gandy drop spreader as following : Cereal Rye -150 lbs/acre; Hairy vetch -55 lbs/acre; then site was passed over with a cultipacker.

\*\*PUBLICATIONS (not previously reported):\*\* 2017/09 TO 2018/08 PROGRESS: 2018/09 TO 2019/08 Target Audience: Our target audience is small- and mid-scale crop producers in Missouri and other areas of the Midwest. This study will introduce innovative and novel research that will be of great interest to the disciplines of agronomy, entomology, horticulture, weed science and plant pathology. The integrated systems approach to addressing the critical management concerns of small farmers is a unique and innovative approach. Changes/Problems: Nothing

Reported What opportunities for training and professional development has the project provided? Three undergraduate students were hired to assist with the planting and maintenance of the plots, etc. Also, to train students with use of remote sensing in agricultural production, a small unmanned aerial Drone equipped with multispectral imagery was flown over the plots and the Images obtained were used in GIS and Remote Sensing course. 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 will continue and repeat the experiments and conduct new experiments at Busby farm. IMPACT: 2018/09 TO 2019/08 What was accomplished under these goals? This is the second year of the project and we repeated the experiments as outlined in objectives. In September 2018, experimental plots were laid out according to the objectives at Lincoln University's Allen T. Busby farm which is certified for organic farming research. Soil samples were taken from all plots and were analyzed for macro- and micro-nutrient content. To meet the second objective, in September 2018 raised beds were formed in the rototilled section of the field and were planted with using a Gandy drop spreader with various mixture of crop crops including Purple Bounty hairy vetch CV untreated (albert lea), Aroostock Rye CV ( untreated albert lea), Cereal rye OG (Johnnys select seeds), Hairy vetch OG (Johnnys select seeds), and tillage Radish OG (High Mowing Seeds). the N-Dure vetch/peas/bean inoculant used which was purchased from Johnnys select seeds). Alleyways of the raised beds were planted with white New Zealand White clover CV untreated and Oats OG. Alleyways and raised beds were passed over with a cultipacker. At the end of September, the designated part of the field was disced and rototilled and seed was spread with as following : Cereal Rye -150 lbs/acre; Hairy vetch -55 lbs/acre; then site was passed over with a cultipacker. In late April 2019 the cover crop bi-culture was planted with a push seeder and watered, as deemed necessary to support even germination, in light of rainfall patterns present at the time. Both cover crops in the mix were terminated at the first frost event of the fall of 2019. In the May of 2019, summer squash was transplanted into transplant sites using hand tools. During the season weed species incidence and abundance was monitored and recorded. Also, pest and insect species were identified. Mid-June 2019 the beet crop was terminated due fungal infection by Leaf Spot. Starting second week in June, zucchini was harvested 3 times per week and data was taken as for the size and fresh weight for each cover crop treatments. Aerial Drone equipped with multispectral imagery was flown over the plots and the Images obtained. PUBLICATIONS (not previously reported): 2018/09 TO 2019/08 Type: Conference Papers and Presentations Status: Accepted Year Published: 2019 Citation: P. Grimes, F. Eivazi, M. Dolan-Timpe. 2019. Evaluation of different cover crop termination methods on soil health and weed suppression. 19th Biennial 1890 Research Symposium Abstracts.

2019/09 TO 2020/08 What was accomplished under these goals? Experimental plots were laid out in September 2019, and the objectives were repeated according to the proposed treatments of cover crops. Data were collected on beets and summer zucchini plants during summer 2020. Soil samples taken in Fall 2019, and Spring 2020 and were processed for microbial community measurements. The activities of enzymes, acid phosphatase, beta glucosidase, arylsulfatase, beta glucosaminidase, dehydrogenase, and phenol oxidase were measured using proper methods and correlated with nutrient and organic matter accumulation under different cover crop treatments. \*\*PUBLICATIONS (not previously reported):\*\* 2019/09 TO 2020/08 No publications reported this period. Is this (2019-20 report) even the right project? Nothing about the innovative cover cropping system or no-till.

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# Advancing the Development of Seed-propagated Hybrid Varieties in Strawberry for Organic Agriculture

<b>Accession No.</b>	1013061
<b>Project No.</b>	NH.W-2017-02424
<b>Agency</b>	NIFA NH.W\
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-27292
<b>Proposal No.</b>	2017-02424
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2020
<b>Grant Amount</b>	\$467,902
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Mahoney, L. L.; Davis, TH, M.; Sideman, RE, GR.

## NON-TECHNICAL SUMMARY

The project is titled "Advancing the development of seed-propagated hybrid varieties in strawberry for organic agriculture". The goal is to produce both day-neutral and short-day flowering strawberry varieties that can be propagated by seed rather than by the conventional runner plant approach. Strawberries are typically propagated vegetatively from runners and purchased by growers as bare-root plants. The major problems are as follows: 1) The process of generating the bare-root plants requires many chemical inputs to avoid transmission of diseases and these chemical inputs may be harmful to the workers and the environment; 2) The grower planting schedule is dictated by the bare-root supplier and therefore planting stock availability is seasonally limited according to the purchaser's climatic region; and 3) Strawberry varieties developed for organic agriculture do not exist, and only one company located in Europe, offers any strawberry seed-propagated varieties. We are employing a breeding method called marker-assisted breeding (MAB), in which traditional cross-hybridization and phenotypic (trait-based) selection is complemented and enhanced by DNA testing using a high throughput technology known as a SNP (single nucleotide polymorphism) array. As a starting point, hybrid strawberry plants are being subjected to multiple cycles of inbreeding and selection as a means of exposing and purging genes for undesirable traits and approaching a true breeding state. From the resulting inbred plants, superior individuals will then be selected for use as parents in crosses to produce F1 hybrid seed, which can then be used to establish acceptably uniform populations of F1 hybrid plants for use in commercial fruit production. The inbreds and F1 hybrid combinations will be selected for traits of interest, including: fruit quality and productivity, vigor and disease resistance. Inbreds and hybrids will be subjected to DNA testing using the IStraw35® strawberry SNP array, which the UNH investigators previously helped to develop as member of the RosBREED (USDA-SCRI) project, and which is marketed by Affymetrix Inc. The results of such DNA testing assist breeders in associating favorable traits with plant genetic makeup in order to guide further cycles of marker-assisted-breeding. Development and selection of the inbred parents and of the F1 hybrids will initially been made at the UNH Macfarlane Greenhouses and Woodman Farm and the best of F1 hybrid populations will be planted at interested grower sites for evaluation. New strawberry varieties that are regionally adapted and suitable for organic agriculture will be made available to New England growers. These locally developed seed propagated varieties are expected to be suitable for organic agriculture in New England and our climatic region. In addition, in contrast to constraints of bare-root plants limited window of availability the seeds can be planted according to the growers' preferred time table.

## OBJECTIVES

The Major Goal of the project is to provide strawberry growers with regionally adapted, seed-propagated strawberry varieties that are suitable for organic agriculture and are pleasing to consumers. Organically-certifiable, seed-propagated varieties provide an attractive and environmentally friendly alternative to the vegetatively propagated varieties currently relied upon by the strawberry industry. The objectives of the project are as follows: 1. Develop inbred selections to serve as parents for production of F1 hybrid seed. 2. Define genetic and phenotypic consequences of inbreeding as a guide to optimization of parent selection and breeding strategy. 3. Evaluate combining abilities of inbreds as parental pairs for hybrid seed production. 4. Engage growers in the evaluation of seed-propagated hybrid strawberry varieties.

## APPROACH

Inbred parents and F1 hybrid seed will be developed: Five pedigrees involving six initial founding parents will be used in generating inbreds, with additional parents and pedigrees to be initiated in year 1. Strawberry fruit resulting from crosses will be harvested and the seeds will be cleaned, and stored. Seeds for planting will be surface sterilized and germinated. Upon initiation of flowering of plants to be inbred, unopened flowers will be protected with fine-mesh bags to enforce self-pollination. Wherever possible, at least 200 seeds will be sown from each unique cross in germination trays. At the end of the process, a subset of up to 50 vigorous seedlings will be transplanted to plug trays. Approximately 4-8 weeks later, up to 30 of the most vigorous plug plants from each cross will be selected and planted in the field. Based upon the outcome of self-pollination, a specified number of vigorous plants that have produced a sufficient abundance of selfed seed will be selected for advancement. These plants will be clonally reproduced and maintained in replicate at the UNH. F1 generation: For each initial cross, the aim will be to select up to 24 F1 plants, which will then be self-pollinated, culminating in the production of a sufficient amount of seed to establish S1 progeny families. Based upon the seed germination and reproductive success of the S1 families, the number of represented F1 founders will ultimately be reduced to six per cross. These six final F1 founder plants (per cross) will be maintained and clonally replicated to insure preservation. S1 and S2 generations: Seed germination and reproductive success will be assessed as described above. S1 and S2 families of up to 30 members each will be assessed. Within each family, up to 15 plants will be chosen for enforced selfing. Depending upon their reproductive success, up to six plants per family will be advanced to seed harvesting. On this basis, with up to six plants per S1 family, we will have up to 72 S1 plants per initial cross. Subsequently, on the basis of S2 family performance, one to three S1 plants will be retained per family. An initial excess of progeny numbers at every stage will be required to insure against loss through selection, particularly with reference to seed germination, seedling vigor, and plant reproductive success. S3 generation: The foregoing process will be used to generate 12 S3 families per cross, each descended from a different F1 founder. From each family, four inbreds will be selected on the basis of sufficient vigor and sexual fecundity for potential use in subsequent inbred × inbred crosses. Additional S generations: The process of selfing will be continued until the degree of uniformity to be found in the F1 hybrid seed progeny is satisfactory. Phenotypic data will be collected at multiple life cycle stages in each generation to include seed germination rates, seedling vigor, floral characteristics, and fruit characteristics. Attention will be paid to the possible occurrence of male sterile S3 individuals, which could be employed as females in subsequent hybrid seed production. Experimental plan and statistical approach: For the initial evaluation at the UNH farm, each of the F1 hybrid seed varieties and a one or two cultivars for comparison will be planted in four completely randomized replicated plots of thirty plants each, an approach similar to (Kaczmarek et al., 2016). The cultivar will be Jewel and/or Tribute depending on whether the F1 hybrid seed varieties are expected to be SD and/or DN respectively. The uniformity of each hybrid seed variety will be evaluated for flowering cycle (weeks in flower), plant vigor (plant diameter) and plant runner production (0 to 9). Fruit traits will include yield, and quality, and flavor. Uniformity per trait will be expressed as the plot coefficient of variation, providing a basis for comparisons of uniformity across hybrid populations. The hybrid seed varieties will be compared to each other and to the comparator cultivars. Hybrid performances will be compared using plot means subjected to ANOVA and methods used by other researchers for comparison inbreds (Shaw et al., 1997) and of strawberry germplasm and cultivars (Kennedy et al., 2013). Genetic determinants of inbreeding depression and assess combining ability of inbreds as parental pairs for F1 hybrid seed production: The marker allele constitutions of the six founding clones and of select progeny plants will be determined by genotyping on the IStraw35 Array. The resulting panel of F1 plants will be subjected to SNP genotyping to define their allele compositions. The six parental plants will be included in all genotyping assays as controls. The allele frequencies at each genotyped SNP locus in these S1, S2, and S3 panels will be determined and compared to the founders and to the F1 seed hybrids and analyzed to identify markers and marker blocks that are over and under-represented, or alleles and marker blocks that are absent in the selected inbreds which may result from population purging due to positive selection for favorable traits. Conversely, an unchanged level of heterozygosity may suggest enforcement of heterozygosity in some genomic regions as requisite for vigor and survival. Finally, phenotypic and marker-based selection will be used to select inbreds for inbred × inbred crosses to assess specific and general combining ability. Outreach Plan: Engage

growers in the evaluation of seed-propagated F1 hybrid varieties: During project year 1, Co-PD Sideman (Extension Specialist) will assist in the selection of interested strawberry growers, the primary stakeholder, in Northern New England (New Hampshire, Maine, Vermont) and conduct outreach activities for coordinating grower trials. In year 2 and 3, PD Mahoney and Co-PD Sideman will visit participating growers to facilitate on-farm trials and evaluations with the aim of identifying one to two growers per state as continuing partners. In year 3, interested participatory growers will receive seed-derived hybrid plant populations of up to 100 plants, and will qualitatively evaluate them on their farms with respect to vigor, productivity, fruit quality, and uniformity. The PD and Sideman or other project representatives will conduct site visits with participating growers during the production season. In addition to engaging growers in the evaluation of seed-propagated hybrid populations, ongoing feedback will be solicited from growers throughout the project timeline via field days, where growers can view and help "select" F1 hybrid varieties at the UNH Woodman farm, and extension research reports on project findings, and presentations at meetings of the Northeast Organic Farming Association, New England Vegetable and Berry Growers, North American Strawberry Growers Association, International Society for Horticultural Science, RosBREED, and others. We will engage in numerous activities aimed at educating students at the University of New Hampshire, as well as strawberry growers and other stakeholders. Over the course of the project we anticipate that at least ten undergraduate students employed as field, greenhouse, and lab helpers will gain valuable knowledge and practical experience. In addition, students in the "Evolutionary Genetics of Plants" and "Plant Domestication: Past, Present, and Future" courses regularly taught by Dr. Davis with contributions by Dr. Mahoney will be exposed to related concepts in crop evolution, genetics, and plant improvement. We will educate growers and stakeholders via technical publications, presentations at grower meetings, publication in scientific journal, presentations at scientific conferences, and maintenance of a project website (now in development). \*\*Progress\*\* 09/01/17 to 08/31/22 \*\*Outputs\*\* Target Audience: Updates on our breeding results to-date have been presented and stakeholder inputs have been obtained at the International Society for Horticultural Science VIII, International Strawberry Symposium, NH Farm and Forest conference, RosBREED meetings, the NOFA-NH Winter Conference, the UNH Spring Macfarlane Open Houses, NASGA conference, ASHS, and UNH NHAES MacFarlane and Woodman Farm tours. Interactions at these and other venues have confirmed that the concept of seed-propagated varieties is viewed as an attractive option by strawberry growers. LL Mahoney, Breeding strawberries for the organic producers, NHAES Pollinator Appreciation Day and Research Field Day, UNH NHAES Woodman Farm, June 19, 2018 (Talk). TM Davis and LL Mahoney, Strawberry Social - Strawberries of New Hampshire: Past, Present, and Future, Temple NH, June 24, 2018 (Talk). LL Mahoney, Breeding strawberries for New Hampshire, interview - Manchester Union Leader, June 29, 2018 issue <http://www.unionleader.com/article/20180730/NEWS02/180729564> (Interview). LL Mahoney, Breeding strawberries, Durham Farm Day, August 18, 2018 - (Talk). LL Mahoney, Breeding Strawberry Varieties, NHAES Greenhouse Open House and Macfarlane Research Event, Durham NH, April 5-6, 2019 (public discourse, tours, and posters on breeding strawberries and planned seed varieties). LL Mahoney, Breeding Strawberry Varieties, NHAES Food and Agriculture Extension Staff Quarterly Meeting, UNH NHAES Woodman Farm, July 25, 2019 (tour of fields and discussion on planned seed varieties). LL Mahoney, Breeding Strawberries Varieties for the Region's Organic Growers, 7th Annual Durham Farm Day, UNH NHAES Woodman Farm, August 17, 2019 (public discourse, tours, and posters on breeding strawberries and planned seed varieties). New England Vegetable and Fruit Conference and Trade Show, Manchester NH, December 10-12, 2019 (LL Mahoney attended and networked on breeding strawberries and planned seed varieties). LL Mahoney, NHAES Virtual Twilight Meeting, June 24, 2020 (presentation on update on strawberry breeding for fruit quality and seed varieties). LL Mahoney, Durham Farm Field Day, August 21, 2021. Featured selections of F1 hybrid are being made for future evaluation by interested growers. LL Mahoney, Breeding Strawberry Varieties at UNH Posters: Breeding Fresh Market Strawberry Varieties, Breeding Ornamental Strawberry Varieties, and Making a strawberry cross, NHAES Greenhouse Open House and Macfarlane Research Event, Durham NH, April 2, 2022 (public discourse, tours, and posters on breeding strawberries and planned seed varieties). LL Mahoney, Strawberry F1 Seed Hybrids, UNH Cooperative Extension Vegetable and Farm Team Tour, UNH NHAES Woodman Farm August 19, 2022 (tour of F1 seed hybrid replicated plots). Changes/Problems: Progress on each of the project objectives was delayed 2020-2021 due to the Covid-19 pandemic. On-site research was limited and on-site visits by the public were prohibited until August 2021. The Covid-19 pandemic required scaling down of research at UNH. Fewer seeds from fewer families were sown as limited access was granted to complete the work. Given that a key output of this OREI project was the engagement of growers in the evaluation of F1 seed hybrids generated from inbreds, the seeds were generated and stored rather than sown. A request was made to extend the project by an additional year, during which time additional inbreeding and F1 hybrid seed could be generated with the anticipation that the summer of 2022 would be post-Covid-19 and permit in-person grower evaluations. Project extension to August 31, 2022, permitted an additional summer of data collection. What opportunities for training and professional development has the project provided? Eight undergraduate students and one graduate student have gained valuable work experience and training in the following: strawberry propagation both seed and vegetative via runners and crown divisions. strawberry inbreeding, fruit collection for

seed harvesting and cleanup. phenotyping in the field for plant vigor, health as well as fruit production and quality fruit quality assays for Brix and acidity plant field and greenhouse maintenance Mentored undergraduate students who presented at the UNH Undergraduate research Conference. A Benner, A Perkins LL Mahoney (2019) Fertilizer Regime for Organic Strawberry Production. UNH COLSA 28th Annual Undergraduate Research Conference, April 27, Durham, NH. T Fischer, M Alix, A Benner, A Perkins, LL Mahoney (2019) Strawberry Breeding. UNH COLSA 28th Annual Undergraduate Research Conference, April 27, Durham, NH. LL Mahoney served on Graduate Master's Thesis committee: Quantifying nutrient and light requirements for day-neutral strawberries in controlled environment agriculture (2019) Anna Elizabeth Devitto Master's Thesis PI Mahoney and Co-PI Davis served as co-advisors on Graduate Master's Thesis committee: The development of knowledge and resources relevant to the genetic manipulation of day neutral flowering habit in strawberry (2020) Samikshya Rijal Master's Thesis How have the results been disseminated to communities of interest? Results and insights gained from this research have been disseminated in multiple venues, including conferences of the North American Strawberry Growers Association, American Society of Horticultural Science, RosBREED, NOFA-NH, the VIII International Strawberry Symposium, and local growers' workshops. Updates on results have been presented at the following public events and meetings. In addition to Zoom and phone conversations with potential parties of interest are on-going and letters of support were provided as part of an OREI grant proposal submitted in January 2021. LL Mahoney, Breeding strawberries for the organic producers, NHAES Pollinator Appreciation Day and Research Field Day, UNH NHAES Woodman Farm, June 19, 2018 (Talk). TM Davis and LL Mahoney, Strawberry Social - Strawberries of New Hampshire: Past, Present, and Future, Temple NH, June 24, 2018 (Talk). LL Mahoney, Breeding strawberries for New Hampshire, interview - Manchester Union Leader, June 29, 2018 issue <http://www.unionleader.com/article/20180730/NEWS02/180729564> (Interview). LL Mahoney, Breeding strawberries, Durham Farm Day, August 18, 2018 - (Talk). LL Mahoney, RG Sideman, TM Davis (2019) Breeding Strawberry Seed Varieties in Northern New England for Organic Agriculture. IX North American Strawberry Symposium, 2019 North American Strawberry Growers Association Annual Meeting, February 3-6, Orlando, Florida. LL Mahoney participated and shared results informally during RosBREED2 hosted Partner's Meeting San Diego, California January 11, 2019 and RosBREED2 Participants Meeting, March 25-28, Lansing, Michigan. LL Mahoney participated and shared results informally and with posters during the NHAES Greenhouse Open House and Macfarlane Research Event, Durham NH, April 5-6, 2019. LL Mahoney (2019) Breeding Strawberry Fruit and Ornamental varieties, UNH Extension Food & Agriculture Program Staff Summer Meeting, July 25 UNH NHAES Woodman Horticultural Farm, Durham NH, July 25 (Talk). LL Mahoney (2019) Breeding Strawberries Varieties for the Region's Organic Growers, 7th Annual Durham Farm Day, August 17 UNH NHAES Woodman Horticultural Farm, Durham NH (Talk). LL Mahoney, New England Vegetable and Fruit Conference and Trade Show attended and networked, Manchester NH, December 10-12, 2019. LL Mahoney, Update on strawberry breeding: flowers, fruit, and seed, NHAES Virtual Twilight Meeting, June 24, 2020. LL Mahoney, Durham Farm Field Day, August 21, 2021. Featured selections of F1 hybrid are being made for future evaluation by interested growers. LL Mahoney, Breeding Strawberry Varieties at UNH Posters: Breeding Fresh Market Strawberry Varieties, Breeding Ornamental Strawberry Varieties, and Making a strawberry cross, NHAES Greenhouse Open House and Macfarlane Research Event, Durham NH, April 2, 2022 (public discourse, tours, and posters on breeding strawberries and planned seed varieties). LL Mahoney, Strawberry F1 Seed Hybrids, UNH Cooperative Extension Vegetable and Farm Team Tour, UNH NHAES Woodman Farm August 19, 2022 (tour of F1 seed hybrid replicated plots). LL Mahoney, Breeding Edible and Ornamental Strawberries for New England, Inspired, 2022 Horticultural Report, Research from the New Hampshire Agricultural Experiment Station, Summer 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. Develop inbred selections to serve as parents for production of F1 hybrid seed. As background, field phenotyping is conducted at the UNH Woodman Farm in certified organic fields and inbreeding is completed at the UNH Macfarlane Greenhouse Facility in a certified organic greenhouse. Seeds anticipated to generate repeat flowering plants are sown in February for field planting in May. The repeat flowering plants begin to bear fruit in the same year in which the seeds are sown and so phenotyping and selections are begun in that first year and completed the second year. Seeds anticipated to generate short-day plants requiring flower initiation, are sometimes later sown in May, and planted in the field in August, and phenotyping is completed the following year. In general, within each inbreeding generation, more seeds are generated than can be sown and therefore the seeds selected for sowing are based on the qualities of the parents with the most desirable fruit quality and productivity, as well as plant health and flowering cycles. Select genotypes are maintained in a greenhouse and some are also planted in the field to reserve as potential parents pending results of progeny tests. Beginning with a set of six cultivars, subsequently expanded to thirteen, we generated a diversity of foundational hybrids, from which twenty-one inbred lineages have been derived, and carried through repeated cycles of inbreeding through self-pollination. We have produced over 160,000 seeds including 16,000 S4 (fourth generation inbred) and 19,000 S5 seeds, and have field evaluated over 7,800 inbred plants. Advances to the sixth generation of inbreeding (S6) were made in two families in 2021. 2. Define genetic and phenotypic consequences of inbreeding as a guide to optimization of parent selection and breeding strategy.

The data analysis on the IStrow SNP genotyping indicates progress on inbreeding is as expected as evidenced by the reduction in heterozygosity and corresponding increase in homogeneity with each selfing generation. Genetic heterozygosity was reduced from a mean of 45% in the founding hybrids to 5% in fourth generation inbred plants, and that hybrid vigor and good fruit quality could be restored in progeny of crosses between fourth generation inbreds. The data analysis on the IStrow SNP genotyping guided the choice of parents for the F1 seed hybrids crosses and choice of seed families sown in February 2021. 3. Evaluate combining abilities of inbred genotypes as parental pairs for hybrid seed production. Initial inter-crossings were completed between potentially promising inbred parents for seedling generation. We have produced F1 seed hybrids via combinatorial crossing of selected inbreds and have thus far evaluated twenty-two F1 seed hybrid populations. Phenotyping revealed high level of heterosis between the distantly related inbred parents and the expected corresponding limited restoration of hybrid vigor between closely related inbred parents and a high level of homogeneity. In addition, two of the progeny families were evaluated for suitability under low tunnel plasticulture for season extension until early November. During the last year of the project, the most fruitful or productive F1 seeds from six families were evaluated in replicated plots for evaluation of flowering habit, heterosis and homogeneity. 4. Engage growers in the evaluation of seed-propagated hybrid strawberry varieties. We have generated interest for the upcoming varieties of initial F1 seeds planned for evaluation summer of 2020 during the following presentation and events. As initial F1 seeds were evaluated on-site summer of 2020, as UNH was not allowed to permit the public to visit UNH facilities and field sites from mid-March: we generated interest in the evaluation of upcoming varieties with a virtual meeting. LL Mahoney, Breeding strawberries for the organic producers, NHAES Pollinator Appreciation Day and Research Field Day, UNH NHAES Woodman Farm, June 19, 2018 (Talk). TM Davis and LL Mahoney, Strawberry Social - Strawberries of New Hampshire: Past, Present, and Future, Temple NH, June 24, 2018 (Talk). LL Mahoney, Breeding strawberries for New Hampshire, interview - Manchester Union Leader, June 29, 2018 issue <http://www.unionleader.com/article/20180730/NEWS02/180729564> (Interview). LL Mahoney, Breeding strawberries, Durham Farm Day, August 18, 2018 - (Talk). NHAES Greenhouse Open House and Macfarlane Research Event, Durham NH, April 5-6, 2019 (public discourse, tours, and posters on breeding strawberries and planned seed varieties). LL Mahoney, Breeding Strawberry Varieties, NHAES Food and Agriculture Extension Staff Quarterly Meeting, UNH NHAES Woodman Farm, July 25, 2019. LL Mahoney, Breeding Strawberries Varieties for the Region's Organic Growers, 7th Annual Durham Farm Day, UNH NHAES Woodman Farm, August 17, 2019. New England Vegetable and Fruit Conference and Trade Show attended and networked, Manchester NH, December 10-12, 2019. LL Mahoney, Update on strawberry breeding: flowers, fruit, and seed, NHAES Virtual Twilight meeting, June 24, 2020. LL Mahoney, Durham Farm Field Day, August 21, 2021. Featured selections of F1 hybrid are being made for future evaluation by interested growers. LL Mahoney, Breeding Strawberry Varieties at UNH Posters: Breeding Fresh Market Strawberry Varieties, Breeding Ornamental Strawberry Varieties, and Making a strawberry cross, NHAES Greenhouse Open House and Macfarlane Research Event, Durham NH, April 2, 2022 (public discourse, tours, and posters on breeding strawberries and planned seed varieties). LL Mahoney, Strawberry F1 Seed Hybrids, UNH Cooperative Extension Vegetable and Farm Team Tour, UNH NHAES Woodman Farm August 19, 2022 (tour of F1 seed hybrid replicated plots). LL Mahoney, Breeding Edible and Ornamental Strawberries for New England, Inspired, 2022 Horticultural Report, Research from the New Hampshire Agricultural Experiment Station, Summer 2022.

**\*\*Publications\*\*** - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: LL Mahoney, Update on strawberry breeding: flowers, fruit, and seed, NHAES Virtual Twilight meeting, June 24, 2020 - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: TM Davis, Y Yang, D Frailey, LL Mahoney (2020) A Pentaploid-Based Linkage Map of an Octoploid Strawberry Hybrid Reveals Unusual Patterns of Recombination, Plant and Animal Genome Conference, January 11-16, San Diego, California - Type: Journal Articles Status: Published Year Published: 2020 Citation: Davis, TM, Y Yang, LL Mahoney, and DC Frailey (2020) A pentaploid-based linkage map of the ancestral octoploid strawberry *Fragaria virginiana* reveals instances of sporadic hyper-recombination. *Horticulture Research* 7:77, 15 - Type: Other Status: Published Year Published: 2019 Citation: LL Mahoney, RG Sideman, TM Davis (2019) Breeding Strawberry Seed Varieties in Northern New England for Organic Agriculture. IX North American Strawberry Symposium, 2019 North American Strawberry Growers Association Annual Meeting, February 3-6, Orlando, Florida. (poster) - Type: Journal Articles Status: Published Year Published: 2020 Citation: Iezzoni, AF, J McFerson, J Luby, K Gasic, V Whitaker, N Bassil, C Yue, K Gallardo, V McCracken, M Coe, C Hardner, JD Zurn, S Hokanson, Evd Weg, S Jung, D Main, CdS Linge, S Vanderzande, TM Davis, LL Mahoney, C Finn, and C Peace (2020) RosBREED: bridging the chasm between discovery and application to enable DNA-informed breeding in rosaceous crops. *Horticulture Research* 7:177, 23. - Type: Theses/Dissertations Status: Published Year Published: 2020 Citation: PI Mahoney and Co-PI Davis served as co-advisors on Graduate Master's Thesis committee: Samikshya Rijal (2020) The development of knowledge and resources relevant to the genetic manipulation of day neutral flowering habit in strawberry, UNH Agriculture, Nutrition and Food Systems Master's Thesis **\*\*Progress\*\*** 09/01/20 to 08/31/21 **\*\*Outputs\*\*** Target Audience: We continued to generate interest in the evaluation for the upcoming varieties as initial F1 seed hybrids during on-site tours at the Durham Farm Field Day

held August 21, 2021. Selections of F1 hybrid are being made for future evaluation by interested growers. The August 2021 Field day was the first permitted on-site Field Day open to the public tour since the summer of 2019, before Covid-19. Changes/Problems: Progress on each of the project objectives was delayed 2020-2021 due to the Covid-19 pandemic. On-site research was limited and on-site visits by the public were prohibited until August 2021. The Covid-19 pandemic required scaling down of research at UNH. Fewer seeds from fewer families were sown as limited access was granted to complete the work. Given that a key output of this OREI project was the engagement of growers in the evaluation of F1 seed hybrids generated from inbreds, the seeds were generated and stored rather than sown. A request was made to extend the project by an additional year, during which time additional inbreeding and F1 hybrid seed could be generated with the anticipation that the summer of 2022 would be post-Covid-19 and permit in-person grower evaluations. What opportunities for training and professional development has the project provided? Undergraduate students have been trained in the following: strawberry propagation both seed and vegetative via runners and crown divisions. strawberry inbreeding, fruit collection for seed harvesting and cleanup. plant tissue collection and preservation for DNA genotyping phenotyping in the field for plant vigor, health as well as fruit production and quality fruit quality assays for Brix and acidity plant field and greenhouse maintenance How have the results been disseminated to communities of interest? Zoom and phone conversations with potential parties of interest are on-going and letters of support were provided as part of an OREI grant proposal submitted in January 2021. What do you plan to do during the next reporting period to accomplish the goals? 1. Develop the inbred selections to serve as parents for production of F1 hybrid seed. During the fall/winter of 2021-2022, limited inbreeding will be completed in the greenhouse on 30 selections from the summer of 2021. Phenotyping and selections of genotypes field planted started during summer of 2021 will be completed during the 2022 season. 2. Define genetic and phenotypic consequences of inbreeding as a guide to optimization of parent selection and breeding strategy. The data analysis will be completed. 3. Evaluate combining abilities of inbred genotypes as parental pairs for hybrid seed production. Evaluation of F1 hybrid seeds field planted during the 2021 season will be completed summer of 2022. The F1 hybrids will be evaluated for progeny vigor and homogeneity. 4. Engage growers in the evaluation of seed-propagated hybrid strawberry varieties. We are planning a special field day during the summer of 2022 to engage growers for future projects. \*\*Impacts\*\* What was accomplished under these goals? 1. Develop inbred selections to serve as parents for production of F1 hybrid seed. Phenotyping and selection on seedlings set in field rows in June 2020 was completed summer of 2021. During the fall/winter of 2020-2021, an additional cycle of inbreeding was completed in the greenhouse on the 100 selections from the summer of 2020. Seeds from best performing inbred genotypes were sown and field planted spring of 2021. Advances in sixth generation of inbreeding (S6) were made in two families. 2. Define genetic and phenotypic consequences of inbreeding as a guide to optimization of parent selection and breeding strategy. The data analysis on the IStraw SNP genotyping guided the choice of parents for the F1 seed hybrids crosses and choice of seed families sown in February 2021. The data analysis will be completed on the genotyping and on the phenotyping. The data analysis will be used in a manuscript preparation and a future project proposal. 3. Evaluate combining abilities of inbred genotypes as parental pairs for hybrid seed production. Based on initial field evaluations of new founder families made during the summer of 2020, additional seeds from a selection of this families were sown in February 2021 and field planted in May 2021 and initial evaluations were made during summer of 2021. Additional crosses between two families of advanced S4 and S5 generation inbreds were completed to generate additional F1 hybrid seeds. The most fruitful or productive F1 seeds were sown in February 2021 and field planted in May 2021 in replicated plots for evaluation of flowering habit, progeny vigor and homogeneity. Phenotyping and evaluations of these new F1 seed hybrid plants during the summer will be completed summer of 2022. In addition, two of the progeny families are being evaluated for suitability under low tunnel plasticulture for season extension until late October/early November 2021. 4. Engage growers in the evaluation of seed-propagated hybrid strawberry varieties. We continue to generate interest in the evaluation for the upcoming varieties as initial F1 seed hybrids via site tours at the Durham Farm Field Day held August 21, 2021. Selections of F1 hybrid seeds will be made for future evaluation by interested growers. The August 2021 Field day was the first permitted on-site Field Day open to the public tour since the summer of 2019, before the Covid-19 pandemic. \*\*Publications\*\*

## PROGRESS

2017/09 TO 2018/08 Target Audience: We have generated interest in the evaluation for the upcoming varieties as initial F1 seeds become available for evaluation early in 2020 for initial grower evaluation during the summer of 2020 at the following events. LL Mahoney, Breeding strawberries for the organic producers, NHAES Pollinator Appreciation Day and Research Field Day, UNH NHAES Woodman Farm, June 19, 2018 (Talk) TM Davis and LL Mahoney, Strawberry Social - Strawberries of New Hampshire: Past, Present, and Future, Temple NH, June 24, 2018 (Talk) LL Mahoney, Breeding strawberries for New Hampshire, interview - Manchester Union Leader, June 29, 2018 issue <http://www.unionleader.com/article/20180730/NEWS02/180729564> (Interview) LL Mahoney, Breeding strawberries, Durham Farm Day, August 18, 2018 - (Talk) Changes/Problems: Nothing Reported What

opportunities for training and professional development has the project provided? Undergraduate students have been trained in the following strawberry propagation both seed and vegetative via runners and crown divisions. strawberry inbreeding, fruit collection for seed harvesting and cleanup. phenotyping in the field for plant vigor, health as well as fruit production and quality fruit quality assays for Brix and acidity plant field and greenhouse maintenance How have the results been disseminated to communities of interest? Initial results have been presented at the following public events: LL Mahoney, Breeding strawberries for the organic producers, NHAES Pollinator Appreciation Day and Research Field Day, UNH NHAES Woodman Farm, June 19, 2018 (Talk) TM Davis and LL Mahoney, Strawberry Social - Strawberries of New Hampshire: Past, Present, and Future, Temple NH, June 24, 2018 (Talk) LL Mahoney, Breeding strawberries for New Hampshire, interview - Manchester Union Leader, June 29, 2018 issue <http://www.unionleader.com/article/20180730/NEWS02/180729564> (Interview) LL Mahoney, Breeding strawberries, Durham Farm Day, August 18, 2018 - (Talk) What do you plan to do during the next reporting period to accomplish the goals? 1. Develop inbred selections to serve as parents for production of F1 hybrid seed. During the fall/winter of 2018-2019, further inbreeding in the greenhouse will be completed on the 206 selections from the summer of 2018. Seeds from best performing inbred parents will be sown for field planting spring of 2019 and summer of 2019. Phenotyping and selections of genotypes field planted during spring and summer of 2018 will be completed. Selections will be propagated for further inbreeding and crossing in the greenhouse during the fall winter of 2019/2020. Phenotyping and selections will be initiated for seedlings planted summer of 2018 and spring of 2019. 2. Define genetic and phenotypic consequences of inbreeding as a guide to optimization of parent selection and breeding strategy. The results of SNP genotyping on the IStraw90 Axiom array of 106 inbreeding pedigree related genotypes will be analyzed for evidence of inbreeding and the results will be used to guide and complete additional SNP genotyping. 3. Evaluate combining abilities of inbred genotypes as parental pairs for hybrid seed production. Additional inter-crossings are planned for fall/winter of 2018-2019 and for the planned initial evaluation for F1 hybrid progeny vigor and homogeneity during the summer of 2019. Crosses between advanced S3 and S4 generation inbreds will be completed to generate F1 hybrid seeds, and the most fruitful or productive F1 seeds will be sown and field planted during the spring and summer of 2019. F1 hybrid plants will be phenotyped and evaluated in the field. Selections will be made and seed generated for evaluation by interested growers. 4. Engage growers in the evaluation of seed-propagated hybrid strawberry varieties. We will continue to generate interest in the evaluation for the upcoming varieties as initial F1 seeds during on-site evaluations during the summer of 2019 via site tours and communications and plan to engage growers on farm evaluations for summer of 2020.

2018/09 TO 2019/08 Target Audience: We generated interest in the upcoming varieties as initial F1 seeds become available in the near future at the following events. NHAES Greenhouse Open House and Macfarlane Research Event, Durham NH, April 5-6, 2019 (public discourse, tours, and posters on breeding strawberries and planned seed varieties). LL Mahoney, Breeding Strawberry Varieties, NHAES Food and Agriculture Extension Staff Quarterly Meeting, UNH NHAES Woodman Farm, July 25, 2019 (tour of fields and discussion on planned seed varieties). LL Mahoney, Breeding Strawberries Varieties for the Region's Organic Growers, 7th Annual Durham Farm Day, UNH NHAES Woodman Farm, August 17, 2019 (public discourse, tours, and posters on breeding strawberries and planned seed varieties). Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Additional Three undergraduate students have been trained in the following strawberry propagation both seed and vegetative via runners and crown divisions. strawberry inbreeding, fruit collection for seed harvesting and cleanup. phenotyping in the field for plant vigor, health as well as fruit production and quality fruit quality assays for Brix and acidity plant field and greenhouse maintenance Mentored undergraduate students who presented at the UNH Undergraduate research Conference. A Benner, A Perkins LL Mahoney (2019) Fertilizer Regime for Organic Strawberry Production. UNH COLSA 28th Annual Undergraduate Research Conference, April 27, Durham, NH. T Fischer, M Alix, A Benner, A Perkins, LL Mahoney (2019) Strawberry Breeding. UNH COLSA 28th Annual Undergraduate Research Conference, April 27, Durham, NH. Served on Graduate Master's Thesis committee: Quantifying nutrient and light requirements for day-neutral strawberries in controlled environment agriculture (2019) Anna Elizabeth Devitto Master's Thesis How have the results been disseminated to communities of interest? Results have shared at meetings and local events LL Mahoney, RG Sideman, TM Davis (2019) Breeding Strawberry Seed Varieties in Northern New England for Organic Agriculture. IX North American Strawberry Symposium, 2019 North American Strawberry Growers Association Annual Meeting, February 3-6, Orlando, Florida. LL Mahoney participated and shared results informally during RosBREED2 hosted Partner's Meeting San Diego, California January 11, 2019 and RosBREED2 Participants Meeting, March 25-28, Lansing, Michigan. LL Mahoney participated and shared results informally and with posters during the NHAES Greenhouse Open House and Macfarlane Research Event, Durham NH, April 5-6, 2019. LL Mahoney (2019) Breeding Strawberry Fruit and Ornamental varieties, UNH Extension Food & Agriculture Program Staff Summer Meeting, July 25 UNH NHAES Woodman Horticultural Farm, Durham NH, July 25 (Talk). LL Mahoney (2019) Breeding Strawberries Varieties for the Region's Organic Growers, 7th Annual Durham Farm Day, August 17 UNH NHAES Woodman Horticultural Farm, Durham NH

(Talk). What do you plan to do during the next reporting period to accomplish the goals? 1. Develop additional more distantly related inbred selections to serve as parents for production of F1 hybrid seed. During the fall/winter of 2019-2020, further inbreeding in the greenhouse will be completed on the 250 selections from the summer of 2019. Seeds from best performing inbred parents will be sown for field planting spring of 2020. Phenotyping and selections of genotypes field planted during spring 2019 will be completed during the 2020 season. Selections will be propagated for further inbreeding and crossing in the greenhouse during the fall winter of 2020/2021. Phenotyping and selections will be initiated for seedlings planted summer of 2020. 2. Define genetic and phenotypic consequences of inbreeding as a guide to optimization of parent selection and breeding strategy. The results of SNP genotyping on the IStraw90 Axiom array of 106 inbreeding pedigree related genotypes demonstrates evidence of inbreeding and the results are being used to guide and complete additional SNP genotyping and to guide selection of parents. 3. Evaluate combining abilities of inbred genotypes as parental pairs for hybrid seed production. Initial crosses between advanced S3 and S4 generation inbreds were completed to generate F1 hybrid seeds, and the most fruitful or productive F1 seeds were sown and field planted during the 2019 season. Initial evaluations indicate that the parental selections used to generate the F1 hybrids are too closely related to generate the hybrid vigor expected. The evaluation of these will be F1 hybrids will be completed during the summer of 2020. Additional inter-crossings are planned for fall/winter of 2019-2020 to generate F1 hybrids from more distantly related parents to begin evaluations during the summer of 2020. F1 hybrid plants will be phenotyped and evaluated in the field. The F1 hybrids are being evaluated for progeny vigor and homogeneity. Selections will be made, and seed generated for evaluation by interested growers. 4. Engage growers in the evaluation of seed-propagated hybrid strawberry varieties. We will continue to generate interest in the evaluation for the upcoming varieties as initial F1 seeds during on-site evaluations during the summer of 2020 via site tours and communications and are planning a special field day during the summer of 2020 to engage growers on farm evaluations.

## IMPACT

2017/09 TO 2018/08 What was accomplished under these goals? The accomplishments completed for each of the objectives are as follows: 1. Develop inbred selections to serve as parents for production of F1 hybrid seed. Field phenotyping is conducted at the UNH Woodman Farm in certified organic fields and inbreeding is controlled and completed at the UNH Macfarlane Greenhouses in a certified organic greenhouse. Seeds anticipated to generate repeat flowering plants are sown in February for field planting in early May. The repeat flowering plants began to fruit in the same year in which the seeds are sown and so phenotyping and selections are begun in that first year. Seeds anticipated to generate short-day requiring flower initiation, are later sown in May and planted in the field in August, and phenotyping is begun the following year. In general, within each inbreeding generation, more seeds are generated than can be sown and therefore the seeds selected for sowing were selected based on the qualities of the parents with the most desirable fruit quality and productivity, and plant health and flowering cycles. In late summer of 2017, just prior to the project start date, 180 genotypes were selected based on field phenotyping and analysis. These genotypes were propagated for further inbreeding completed in the greenhouse during the fall and winter 2017-2018. Seeds were sown in February and May, and so during the growing season of 2018, 2,200 seedlings were transplanted to the field and the genotypes inbred during the winter of 2017-2018 were also planted in the field to reserve as potential parents pending results of progeny tests. During the summer of 2018, field phenotyping was completed on the previously field planted 1,770 seedlings and begun on the additional 2,200 seedlings. Selection of 206 genotypes were propagated for further inbreeding in the greenhouse during the fall/winter of 2018-2019. Advances to the fourth generation of inbreeding (S4) were made in two families. 2. Define genetic and phenotypic consequences of inbreeding as a guide to optimization of parent selection and breeding strategy. Plant tissue was collected on 106 inbreeding pedigree related genotypes for DNA isolation and Axiom IStraw90 SNP array genotyping and results are expected before the end of the calendar year. 3. Evaluate combining abilities of inbred genotypes as parental pairs for hybrid seed production. Inter-crossings were completed between potentially promising inbred parents for seedling generation. 4. Engage growers in the evaluation of seed-propagated hybrid strawberry varieties. We have generated interest for the upcoming varieties of initial F1 seeds planned for evaluation summer of 2020 during the following presentation and events: LL Mahoney, Breeding strawberries for the organic producers, NHAES Pollinator Appreciation Day and Research Field Day, UNH NHAES Woodman Farm, June 19, 2018 (Talk) TM Davis and LL Mahoney, Strawberry Social - Strawberries of New Hampshire: Past, Present, and Future, Temple NH, June 24, 2018 (Talk) LL Mahoney, Breeding strawberries for New Hampshire, interview - Manchester Union Leader, June 29, 2018 issue <http://www.unionleader.com/article/20180730/NEWS02/180729564> (Interview) LL Mahoney, Breeding strawberries, Durham Farm Day, August 18, 2018 - (Talk) \*\*PUBLICATIONS (not previously reported):\*\* 2017/09 TO 2018/08 No publications reported this period.

2018/09 TO 2019/08 What was accomplished under these goals? 1. Develop inbred selections to serve as parents for production of F1 hybrid seed. Field phenotyping is conducted at the UNH Woodman Farm in certified organic fields and inbreeding is controlled and completed at the UNH Macfarlane Greenhouses in a certified organic greenhouse. Seeds anticipated to generate repeat flowering plants are sown in February for field planting in early May. The repeat flowering plants began to fruit in the same year in which the seeds are sown and so phenotyping and selections are begun in that first year. Seeds anticipated to generate short-day requiring flower initiation, are later sown in May and planted in the field in August, and phenotyping is begun the following year. In general, within each inbreeding generation, more seeds are generated than can be sown and therefore the seeds selected for sowing were selected based on the qualities of the parents with the most desirable fruit quality and productivity, and plant health and flowering cycles. Seeds were sown in February and May, and so during the growing season of 2018, 2,200 seedlings were transplanted to the field and the genotypes inbred during the winter were maintained in another greenhouse and some were also planted in the field to reserve as potential parents pending results of progeny tests. Selection of 206 genotypes were propagated for further inbreeding in the greenhouse during the fall/winter of 2018-2019. From amongst, the seeds generated, seeds of 56 families were selected and sown in February 2019. From each family, up to 50 of the best seedlings were transplanted and of these 1,300 individual genotypes were set in field rows in May 2019. The phenotyping was completed on the 2,200 seedlings planted during the during 2018, and a selection of 250 genotypes were propagated for further inbreeding during the fall/winter of 2019-2020. Advances in fifth generation of inbreeding (S5) were made in two families. 2. Define genetic and phenotypic consequences of inbreeding as a guide to optimization of parent selection and breeding strategy. IStraw SNP genotyping was completed on 192 individuals and initial data analysis indicates progress on inbreeding is as expected as demonstrated by the reduction in heterozygosity and corresponding increase in homogeneity. 3. Evaluate combining abilities of inbred genotypes as parental pairs for hybrid seed production. Inter-crossings were completed between potentially promising inbred parents for seedling generation. Development of F1 hybrids for evaluation of homogeneity were made from intercrossing members of S4 families. The F1 hybrids seeds from 16 crossings were sown, and transplants of 350 were set in fields in May 2019 for evaluation. 4. Engage growers in the evaluation of seed-propagated hybrid strawberry varieties. We have generated interest in the evaluation for the upcoming varieties as initial F1 seeds become available evaluation summer of 2020 via the following. NHAES Greenhouse Open House and Macfarlane Research Event, Durham NH, April 5-6, 2019 (public discourse, tours, and posters on breeding strawberries and planned seed varieties. LL Mahoney, Breeding Strawberry Varieties, NHAES Food and Agriculture Extension Staff Quarterly Meeting, UNH NHAES Woodman Farm, July 25, 2019. LL Mahoney, Breeding Strawberries Varieties for the Region's Organic Growers, 7th Annual Durham Farm Day, UNH NHAES Woodman Farm, August 17, 2019. \*\*PUBLICATIONS (not previously reported):\*\* 2018/09 TO 2019/08 Type: Other Status: Other Year Published: 2019 Citation: LL Mahoney, RG Sideman, TM Davis (2019) Breeding Strawberry Seed Varieties in Northern New England for Organic Agriculture. IX North American Strawberry Symposium, 2019 North American Strawberry Growers Association Annual Meeting, February 3-6, Orlando, Florida. (poster) \*\* \*\*

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# Managing the Most Significant Biotic Challenges for Organic Onion Production Across the Great Lakes Region

<b>Accession No.</b>	1013009
<b>Project No.</b>	NYG-621585
<b>Agency</b>	NIFA NY.G\
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26816
<b>Proposal No.</b>	2017-02467
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2020
<b>Grant Amount</b>	\$836,804
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Nault, B. A.; Havey, MI, J.; Pethybridge, SA, J.; Hay, FR, S..

## NON-TECHNICAL SUMMARY

Organic onions are a highly valuable commodity in the Great Lakes region and their economic viability has been critically threatened by pests and pathogens that are difficult to manage. Stakeholders have identified onion thrips, *Thrips tabaci*, as the most serious insect pest and *Stemphylium* leaf blight (SLB), which is caused by *Stemphylium vesicarium*, as the most important foliar pathogen in this region. The long-term goal of this project is to develop and implement an effective IPM program for onion thrips and SLB that will ensure the sustainability and profitability of organic onion production in the Great Lakes. To meet this goal, the following objectives are proposed: 1) Evaluate OMRI-approved crop protectants in combination with thrips-resistant onions to manage thrips and SLB, 2) Implement and demonstrate an IPM strategy for thrips and SLB using resistant onions and OMRI-approved crop protectants in participating organic growers' fields, 3) Develop and release new early-maturing, multiple-pest-resistant onion cultivars for organic growers, and 4) Deliver project information and develop web-based resources for organic onion producers to implement our IPM program. Our project directly aligns with USDA-OREI program foci such as a) facilitating the development and improvement of organic agriculture production; b) conducting advanced on-farm research on organic farms that improves production; c) developing new and improved seed varieties that are particularly suited for organic agriculture. Moreover, two of these foci (a and c) directly align with the FY2017 USDA-OREI Program priorities.

## OBJECTIVES

Organic onion producers are challenged by insect pests and diseases that routinely cause serious losses and reduce profits. Onion thrips, *Thrips tabaci*, has been prioritized by stakeholders as the most serious pest in both conventional and organic onion production in the Great Lakes region. Thrips feeding damages onion foliage and significantly reduces the number of bulbs reaching marketable sizes. Onion thrips also transmits important pathogens such as Iris yellow spot virus (IYSV) and those that cause bacterial bulb rots. Thrips damage also may create additional entry points that facilitate infection by *Stemphylium vesicarium*, which causes *Stemphylium* leaf blight (SLB). SLB has recently emerged as the most serious foliar disease of onion in the Great Lakes region. SLB damages foliage that may reduce the size of marketable bulbs; SLB also may kill plants prematurely and can result in complete crop loss. Organic onion growers in the Great Lakes region urgently need an effective integrated pest management (IPM) program for onion thrips and SLB to avoid serious losses. We propose to develop and implement an IPM program that is based on a combination of host plant resistance and crop

protectants that are approved by the Organic Materials Re-view Institute (OMRI). We have demonstrated that onions with unique cuticular-wax profiles ("semi-glossy" foliage) significantly reduce thrips damage and these selections may be less vulnerable to SLB. We also have identified some promising OMRI-approved crop protectants that may significantly reduce damage by onion thrips and SLB. The long-term goal of this research is to ensure the sustainability and profitability of organic onion production by developing and implementing an IPM program for thrips and SLB that will combine thrips-resistant cultivars and an OMRI-approved crop protectant program. There are four objectives that we have proposed to meet this long-term goal. The first objective is to evaluate OMRI-approved crop protectants with semi-glossy onions for onion thrips and Stemphylium leaf blight management. This will be accomplished by evaluating OMRI-approved crop protectants for thrips and SLB management on semi-glossy and standard waxy onions and evaluating co-applications of the best performing OMRI-approved crop protectants in a season-long thrips and SLB control program on semi-glossy and standard waxy onions towards the development of an IPM program. The second objective is to implement and assess the IPM strategy for onion thrips and Stemphylium leaf blight using resistant onions and OMRI-approved crop protectants in growers' fields. This will be accomplished by implementing this IPM strategy in organic growers' fields and compare levels of thrips damage, SLB damage and marketable yields of semi-glossy onions with those of a standard waxy onion managed following the growers' practices. The third objective is to develop and release new early-maturing, multiple-pest-resistant onion cultivars for organic growers. This will be done by releasing open-pollinated, semi-glossy, multiple-pest-resistant onion cultivars to stakeholders that minimize losses caused by onion thrips and SLB. The fourth objective is to deliver project information and develop web-based resources for organic onion producers to implement our IPM program for thrips and Stemphylium leaf blight. This will be accomplished by presenting organic onion IPM information at regional and national stakeholder meetings, developing web-based resources for researchers, extension educators, growers and consumers of organically produced onion, hosting field days to showcase onions produced via the IPM program, publishing research results in the scientific and lay press, and assessing the impact and knowledge gained about onion IPM by organic onion growers.

## APPROACH

We will evaluate OMRI-approved crop protectants with semi-glossy onions for onion thrips and Stemphylium leaf blight (SLB) management. Field trials will be established at organic farm in New York to evaluate combinations of thrips-resistant cultivars and OMRI-approved pesticides. The proposed cultivars will include a semi-glossy onion phenotype with low amounts of wax, a semi-glossy phenotype with medium amounts of wax, and a waxy cultivar with high amounts of wax (= standard). Insecticides that have shown promise in preliminary field trials will be evaluated. The treatment design will be an onion selection by insecticide factorial with treatments established as a randomized complete block design and replicated four times. Onions will be transplanted in early May into raised beds covered with reflective silver plastic mulch and drip tape. Insecticides will be applied in mid-June when densities of onion thrips reach an action threshold of 1 per leaf. Additional applications will be made at 7-day intervals for approximately 6 weeks or until the crop has matured normally (leaves fall over). Efficacy of treatments will be evaluated by recording the number of onion thrips larvae and adults per plant from 15 randomly selected plants per plot approximately one week after each application. Data collection will be completed when the crop is nearly mature. Damage ratings will be made every two weeks. Plots will be harvested and bulbs graded according to USDA standards (jumbo, standard and boiler) and weighed. Sub-samples of 50 bulbs will be inspected for fungal and bacterial rots. Fungicides that have shown promise in preliminary field trials also will be evaluated. The location of field trials, years that trials will be conducted, onion selections, method of pesticide application, etc. will be exactly as described previously. The treatment design will be an onion selection by fungicide factorial with treatments established as a randomized complete block design and replicated four times. Applications will begin in late-June when SLB lesions are first detected. Additional applications will be made at 7-day intervals for approximately 6 weeks or until the crop has matured normally. Products that previously have shown efficacy against SLB and other fungal pathogens in conventional onions and those whose efficacy is unknown will be evaluated. Disease assessments will be made weekly within the center of each plot. Disease lesions will be assessed by counting the number of lesions per leaf and by visual estimation of the severity on 20 leaves per plot. Leaves will be incubated in humid containers for 7 days and observed under the microscope to identify fungi associated with lesions under the microscope. Bulbs will be harvested, weighed and inspected for disease as mentioned previously. The best performing OMRI-approved crop protectants will be evaluated in season-long programs to manage onion thrips and SLB on semi-glossy and the standard waxy phenotypes. The location of these field trials, onion cultivars, plot size, plant spacing, method of application, harvest and grading, etc. will be exactly as described previously; however, the experiments will be conducted in subsequent years. The treatment design will be a 5 crop protectant program (3 potential crop protectant programs, a standard spray program and an untreated control) by 3 onion selection factorial. Treatments will be established as a randomized complete block design with four replicates per treatment. Applications will begin in mid to late-June when onion

thrips reach an action threshold of 1 thrips/leaf and when SLB lesions are first detected. However, if these events do not occur simultaneously, the sequences of insecticides and fungicides can be staggered in time after the initial thresholds are reached. Additional applications will be made at 7-day intervals for approximately 6 weeks or until the crop has matured normally. However, reductions in application frequency will be made if thrips densities are well below threshold on certain dates in certain onion selection by OMRI material program treatments. Efficacy of treatments, yield assessment, etc. will be determined as described previously. The best IPM strategy for onion thrips and SLB identified in small plot studies will be evaluated in organic growers' fields in New York and Wisconsin. Growers will transplant onions and maintain all aspects of the crop, with the exception of controlling insects and diseases; we will make all crop protectant applications on the farm. This experiment will be conducted using two cultivars: a thrips-resistant, semi-glossy wax cultivar with medium amounts of wax and a standard waxy cultivar of similar maturity that is grown on the organic farm. The OMRI-approved crop protectant program identified above will be used for thrips and SLB control on half of the thrips-resistant onion cultivar and half of the standard waxy cultivar. The organic growers' insect and disease management program will be followed on the other half of the onion plots. Thus, there will be four treatments: thrips-resistant selection + OMRI-approved program, thrips-resistant selection + grower's management program, standard waxy cultivar + OMRI-approved program, and standard waxy cultivar + grower's management program. Each treatment will be replicated 3 times on each farm. Crop protectants will be applied using the equipment and approach described above. Thrips densities and SLB lesions will be monitored weekly in all fields. Thirty plants will be randomly selected within each plot and the numbers onion thrips larvae and adults recorded. A visual rating of thrips damage on these thirty plants will be made every other week. SLB lesions and severity of lesions on the leaves also will be assessed weekly from 30 randomly selected plants within each plot. After onions have matured, they will be harvested within each plot to measure bulb yields and sizes. New early-maturing, multiple-pest-resistant onion cultivars will be released for organic growers. An existing onion selection with resistance to two other pathogens will be crossed with best selection with thrips resistance. This multiple-pest-resistant selection is early maturing, has waxy foliage, and produces bulbs with relatively good storage abilities for marketing over the fall and winter months. This inbred will be crossed with the best semi-glossy selections that support fewer thrips and suffer less feeding damage, and F3 families produced. Semi-glossy F3 families will be visually identified and gas chromatography mass spectrometry used to measure amounts of cuticular waxes, selecting families with higher amounts of waxes. Semi-glossy families will be grown in replicated field plots in organic fields in Wisconsin with commercial cultivars. These plots will not be sprayed and thrips numbers and damage will be assessed as described previously. Maturity of families will be scored and bulb yields, sizes, and storage ability over the winter measured. Plants from the early maturing families with good bulb production and storage will be intercrossed and seed will be separately harvested off of each plant to produce half-sib (HS) families. At the end of the project, these HS families will be evaluated for maturity in replicated trials in organic fields in New York and Wisconsin. Bulbs from the best performing families will be harvested and intercrossed to produce early-maturing, yellow-bulb, well storing, and multiple pest-resistant populations to be released to growers and seed companies. Because populations will possess male-fertile cytoplasm, growers will be able to produce their own seed and make selections in their specific environments. Over the long term, populations can be used to develop superior male-sterile lines for hybrid production. **\*\*Progress\*\*** 09/01/17 to 08/31/22 **\*\*Outputs\*\*** Target Audience: Knowledge gained from our on-farm research trials were shared through presentations at organic grower meetings in New York and Wisconsin. We also shared knowledge with a broader stakeholder audience through extension articles published via Cornell Cooperative Extension newsletters like VegEdge as well as the trade magazine, Onion World. Finally, we published our research results in multiple peer-reviewed journals to reach scientific audiences. **Changes/Problems:** The lack of effective insecticides for onion thrips control and lack of insecticides for Stemphylium leaf blight control precluded our ability to evaluate a season-long OMRI-listed pesticide program from these two pests. Instead, we examined the relationship between thrips abundance and bacterial rot incidence as well as the relationships between thrips and yield and bacterial rot and yield for both the hybrid &#39;USDA-Maia&#39; (B5336AxB5351C) and Bradley cultivars. We learned that only occasionally thrips abundance will be positively correlated with bulb rot, but that this relationship is relatively weak in both cultivars. Therefore, thrips control is important, but should not be expected to lower levels of bacterial bulb rot in both cultivars. COVID restricted the rate of progress due to limited access to greenhouse and lab facilities and hiring personnel to assist in research projects. However, the no-cost extensions were invaluable to allow us to successfully complete all of the objectives of this project. What opportunities for training and professional development has the project provided? Two post-doctoral researchers were trained at Cornell during this project. Lindsay Iglesias worked on this project during the early years, and is now employed as an Entomologist Lead, Discovery Biology with Greenlight Biosciences in Durham, NC. Pin-Chu Lai continued this project and is currently searching for a position in academia or industry. In addition to training that Lindsay and Pin-Chu obtained working in the Nault lab, both engaged in a Post-doctoral Workshop Series at Cornell that helped them in their professional development. Both received a certificate of participation for this workshop. The last graduate student (Derek Hunsaker) at Wisconsin who was supported by this project graduated in August 2020. He is now

employed as an Assistant Scientist with the Crop Innovation Center at the UW-Madison. How have the results been disseminated to communities of interest? Details about how results were disseminated to communities of interest are recorded in other sections of this report. We targeted organic vegetable growers who grow onions, the biopesticide industry, crop consultants, extension educators and the scientific community. Results were communicated via face-to-face presentations, extension articles, trade magazine articles and peer-reviewed journal manuscripts. Information also was made available on the websites managed by the PI and Co-PIs. What do you plan to do during the next reporting period to accomplish the goals? In New York, there are no immediate plans to present information from this project. However, information generated from this project likely will be relayed to stakeholder audiences at future meetings. PI Brian Nault and collaborators will continue to update their websites with results from this project as well as general information on organic onion production and management of onion thrips and *Stemphylium* leaf blight. In Wisconsin, GCMS analysis of additional sources of semi-glossy foliage associated with thrips resistance will be completed in 2023 and one more publication will be published in 2024.

**\*\*Impacts\*\*** What was accomplished under these goals? Objective 1 Objective 1 consisted of two projects: 1) to evaluate OMRI-Listed bioinsecticides in combination with different adjuvants and 2) to evaluate plastic mulches and resistant cultivars in combination with bioinsecticides to manage onion thrips. Both of these trials were completed and results and findings were shared at grower-based meetings and published in extension newsletters, trade magazines, and peer-reviewed publications. Growers now are aware of the best options for managing thrips in organically produced onion. Objective 2 On-farm trials were conducted on two organic farms in NY from 2019 to 2021 and one organic farm in WI in 2020. These trials combined the best OMRI-listed insecticides, a semi-glossy thrips resistant cultivar, and silver reflective mulch for onion thrips management. Trials were completed successfully. Results from these trials were summarized, and results have been published in an extension article, trade magazine and peer-reviewed journal focusing on the performance of the semi-glossy resistant cultivar and the relationship between thrips and bacterial bulb rot. Growers now are aware of the best options for managing thrips in organically produced onion as a result of this research. Objective 3 The USDA officially released the hybrid 'USDA-Maia' (B5336AxB5351C) in February 2021, the first hybrid onion with semi-glossy foliage showing thrips resistance for production on high organic (muck) soils of the eastern USA and Canada. Seeds of the inbred parents (B5336A, B5336B, and B5351C) were provided to 16 companies or public-sector breeding programs for use in their respective programs and production of the hybrid 'USDA-Maia'. Although the inbreds of this hybrid were selected and developed over many years before the OREI grant, funds from this grant were imperative to documentation of the level of thrips resistance exhibited by the hybrid. The 'USDA-Maia' hybrid has round bulbs with yellow skins and excellent storage ability, resistance to pink root and *Fusarium* basal rot, and has lower pungency compared to current eastern-storage hybrids. A major publication on the genetics of resistance to *Fusarium* basal rot was published. Development of semi-glossy onions with *Fusarium* resistance was a major goal of this project. A major publication (*Hortscience* 5:1059-1063) on the natural phenotypic diversity for epicuticular wax profiles on was published and identified germplasm accessions with unique wax profiles useful for development of thrips resistant onions. Objective 4: Results from the on-farm trials were published in peer-reviewed journals, an trade magazine article (*Onion World* - most popular trade magazine for onion growers), and an article in the Cornell Cooperative Extension (CCE) *VegEdge* magazine in 2022. Other results were reported in previous years and are shown in the annual progress reports.

**\*\*Publications\*\*** - Type: Journal Articles Status: Published Year Published: 2022 Citation: Lai, P.-C., L. Iglesias, R.L. Groves, M.J. Havey, and B.A. Nault. 2022. Performance of a semi-glossy onion hybrid in certified organic onion fields infested with *Thrips tabaci* and bulb-rot causing bacteria. *Crop Protect.* 160 (1-9). <https://doi.org/10.1016/j.cropro.2022.106037>. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Hay, F. S., Stricker, S., Gossen, B. D., McDonald, M. R., Heck, D. W., Hoepfing, C. A., Sharma, S., and Pethybridge, S. J. 2021. *Stemphylium* leaf blight of onion: A re-emerging threat to onion production in eastern North America. *Plant Dis.* 105:3780-3794. <https://doi.org/10.1094/PDIS-05-21-0903-FE> - Type: Journal Articles Status: Published Year Published: 2022 Citation: Hay, F. S., Heck, D. W., Sharma, S., Klein, A., Hoepfing, C., and Pethybridge, S. J. 2022. *Stemphylium* leaf blight of onion. *Plant Disease Lesson. The Plant Health Instructor* 22: 10.1094/PHI-P-2022-01-0001 - Type: Journal Articles Status: Published Year Published: 2022 Citation: Havey, M.J. 2022. Variation for epicuticular waxes among plant introductions of onion. *Hortscience* 5:10591063. <https://doi.org/10.21273/HORTSCI16697-22> - Type: Other Status: Published Year Published: 2022 Citation: Lai, P.-C., and B. Nault. 2022. Are onion thrips allies of bulb-rot causing bacteria in organic onion production? Cornell Cooperative Extension, Cornell Vegetable Program. *VegEdge* 18(16): 9-10. [https://rvpadmin.cce.cornell.edu/pdf/veg\\_edge/pdf247\\_pdf.pdf](https://rvpadmin.cce.cornell.edu/pdf/veg_edge/pdf247_pdf.pdf) - Type: Other Status: Published Year Published: 2022 Citation: Lai, P.-C. and B. Nault. 2022. Do thrips facilitate bulb rot disease? *Onion World* 38(8): [https://issuu.com/columbiamediagroup/docs/onion\\_world\\_december\\_2022?fr=sMzU1YzQ5MDQ1MjQ](https://issuu.com/columbiamediagroup/docs/onion_world_december_2022?fr=sMzU1YzQ5MDQ1MjQ)

**\*\*Progress\*\*** 09/01/20 to 08/31/21 **\*\*Outputs\*\*** Target Audience: The fourth year of the project continued research on two organic farms in NY focusing on optimizing onion thrips management in organic onion production systems. For reasons related to the COVID-19 pandemic, we elected to not have a 2021 summer workshop or demonstration trial. Rather, knowledge gained from the on-farm trials from 2019 to 2021 will be shared through a

handout and/or a presentation at 2022 Organic Vegetable Production Conference in February 2022 in WI, Empire state producers EXPO in January 2022 in NY, and 2022 NOFA-NY Winter conference in January 2022 in NY. We also plan to share the knowledge with a broader audience through extension articles in Cornell Cooperative Extension newsletters like VegEdge and the trade magazine, Onion World, in early 2022. Changes/Problems: The lack of effective insecticides for onion thrips control and lack of insecticides for Stemphylium leaf blight control precluded our ability to evaluate a season-long OMRI-listed pesticide program from these two pests. Instead, we examined the relationship between thrips abundance and bacterial rot incidence as well as the relationships between thrips and yield and bacterial rot and yield for both the hybrid 'USDA-Maia' (B5336AxB5351C) and Bradley cultivars. We learned that only occasionally will thrips abundance will be positively correlated with bulb rot, but that this relationship is relatively weak in both cultivars. Therefore, thrips control is important, but should not necessarily be expected to lower levels of bacterial bulb rot in both cultivars. COVID restricted progress due to limited access to greenhouse and lab facilities in Wisconsin. We could also not hire an undergraduate student for help with work due to COVID restrictions of lab access. What opportunities for training and professional development has the project provided? The previous postdoctoral researcher who worked on this project is now employed as an Entomologist Lead, Discovery Biology with Greenlight Biosciences in Durham, NC. We recruited another postdoctoral researcher to continue the on-farm trials in 2021. She presented results from the on-farm trials conducted in 2019 to 2021 at the Entomological Society of America Annual Meeting in November in 2021. She will be involved in extension conferences and grower meetings in early 2022 to share results from this study. She is also preparing a manuscript and several extension articles documenting the findings from the on-farm trials. The last graduate student (Derek Hunsaker) at Wisconsin who was supported by this project graduated in August 2020. He is now employed as an Assistant Scientist with BASF Vegetables in Brooks, OR and works with onion breeding and genetics. How have the results been disseminated to communities of interest? Efforts to transfer knowledge about our research in 2021 were stymied by COVID-19. Therefore, there were no presentations to onion growers and other stakeholders in 2021 due to COVID restrictions. Efforts will be made to disseminate our results to growers in 2022. However, results from the on-farm trials were presented at the Entomological Society of America Annual Meeting in November in 2021. Additionally, a summary of the thrips resistance work will be presented at the 2022 National Allium Research Conference in February 2022. What do you plan to do during the next reporting period to accomplish the goals? In New York, we will focus on dissemination of the information obtained from the on-farm study. More specifically, a manuscript summarizing the findings of the on-farm trials will be submitted for publication in 2022. A handout with highlights of the results was created and will be disseminated in extension conferences and meetings in early 2022, which include 2022 Organic Vegetable Production conference, NOFA-NY Winter conference, empire state EXPO, and regional growers meetings in NY. The website of the Brian Nault Laboratory will be updated with results from both years of the project and general information on organic onion production, onion thrips, and stemphylium leaf blight. In Wisconsin, we are completing GCMS analysis of additional sources of semi-glossy foliage associated with thrips resistance. These analyses should be completed in the spring of 2022 and expect one more publication will be submitted in 2022: Havey, M.J., and D. Hunsaker. 2021. Variation for epicuticular waxes among plant introductions and a synthetic population of onion. HortScience (in preparation). **\*\*Impacts\*\***

What was accomplished under these goals? Objective 1 Objective 1 consisted of two projects: 1) to evaluate OMRI-Listed bioinsecticides in combination with different adjuvants and 2) to evaluate plastic mulches and resistant cultivars in combination with bioinsecticides to manage onion thrips. Both of these trials were completed in 2019. Results and findings were published as in two publications in 2021. Objective 2 The on-farm trials were conducted on two organic farms in NY from 2019 to 2021 and one organic farm in WI in 2020. These trials combined the best OMRI-listed insecticides, a semi-glossy thrips resistant cultivar, and silver reflective mulch for onion thrips management. Trials were completed successfully. Results from these trials were summarized, and a manuscript is being prepared focusing on the performance of the semi-glossy resistant cultivar and the relationship between thrips and bacterial bulb rot. Objective 3 The USDA officially released the hybrid 'USDA-Maia' (B5336AxB5351C) in February 2021, the first hybrid onion with semi-glossy foliage showing thrips resistance for production on high organic (muck) soils of the eastern USA and Canada. Seeds of the inbred parents (B5336A, B5336B, and B5351C) were provided to 16 companies or public-sector breeding programs for use in their respective programs and production of the hybrid 'USDA-Maia'. Although the inbreds of this hybrid were selected and developed over many years before the OREI grant, funds from this grant were imperative to documentation of the level of thrips resistance exhibited by the hybrid. The 'USDA-Maia' hybrid has round bulbs with yellow skins and excellent storage ability, resistance to pink root and Fusarium basal rot, and has lower pungency compared to current eastern-storage hybrids. A major publication on the genetics of resistance to Fusarium basal rot was accepted for publication. Development of semi-glossy onions with Fusarium resistance was a major goal of this project. Objective 4: Results from the on-farm trials were presented at a national entomological conference in 2021. We plan to provide information and knowledge obtained from this project to onion growers, University Extension educators and faculty, and the public via a handout that will be distributed during the 2022 Organic Vegetable Production Conference, Empire state producers EXPO, and NOFA-NY Winter

conference, and via an updated article in *Onion World* (most popular trade magazine for onion growers), an article in the Cornell Cooperative Extension (CCE) *VegEdge* magazine in early 2022. \*\*Publications\*\* - Type: Journal Articles Status: Published Year Published: 2021 Citation: Havey, M. J., Hunsaker, D. J., and E.D. Munaiz. 2021. Genetic analysis of the unique epicuticular wax profile of Odourless Greenleafonion. *J. Amer. Soc. Hort. Sci.* 146:118-124. <https://doi.org/10.21273/JASHS05024-20> - Type: Journal Articles Status: Published Year Published: 2021 Citation: Iglesias, L., R. L. Groves, B. Bradford, R. S. Harding, and B. A. Nault. 2021. Evaluating combination of bioinsecticides and adjuvants for managing Thrips tabaci (Thysanoptera: Thripidae) in onion production systems. *Crop Prot.* 142: 105527. <https://doi.org/10.1016/j.cropro.2020.105527> - Type: Journal Articles Status: Published Year Published: 2021 Citation: Iglesias, L., Havey, M. J., and B. A. Nault. 2021. Management of onion thrips (Thrips tabaci) in organic onion production using multiple IPM tactics. *Insects.* 12:207. <<https://doi.org/10.3390/insects12030207>>. - Type: Journal Articles Status: Awaiting Publication Year Published: 2022 Citation: Straley, E., J. Marzu, and M.J. Havey. 2022. Genetic analyses of resistance to Fusarium basal rot in onion. *MDPI Horticulturae* .

## PROGRESS

2017/09 TO 2018/08 Target Audience: The first year of the project was focused primarily on field research, which was still in progress at the end of this project period. However, we were able to provide information about the ongoing field research to onion growers, University Extension educators and faculty, and the public. Efforts to transfer knowledge about our research occurred primarily at the research field sites. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? The project involved mentoring a postdoctoral researcher who will focus on this research as a major component of her appointment. She has also been invited to give a talk about the results of the project at the Eastern Branch Meeting of the Entomological Society of America (EB-ESA) in March 2019. This experience will provide an excellent professional development and science communication opportunity. This project also involved mentoring a high school student during a summer internship and an undergraduate student during Cornell University's Summer Scholars Program. Both students were mentored in experimental design, sample collection and processing, insect identification, and organic agriculture. This project supported a graduate student at University of Wisconsin who completed evaluations for pink root and Fusarium resistances in semi-glossy selections from the USDA onion breeding program. An undergraduate worker gained field experience with seed and bulb production of onion. How have the results been disseminated to communities of interest? The objectives of the project and research progress have been disseminated to onion growers, University Extension educators and faculty, and the public. Efforts to transfer knowledge about our research occurred primarily at the research field sites during site visits. Additional conference and Extension presentations, field visits, and workshops will occur in year two of the project. What do you plan to do during the next reporting period to accomplish the goals? Research plans for next reporting period include repeating the experiments from year 1 during year 2 at University research farms in NY and WI. Additionally, the best OMRI-listed products and thrips-resistant onion varieties for managing onion thrips and *Stemphylium* leaf blight in onions will be evaluated together in an experiment on a grower's farm in both states. Results of the project will be shared at the Northeast Organic Farmers Association of New York (NOFA-NY) Annual Winter Conference in January 2019, the Great Lakes Fruit and Vegetable EXPO in December 2018, and the Eastern Branch Meeting of the Entomological Society of America in March 2019. A field day is also being planned for the summer of 2019 with NOFA-NY to share the results of the research project to our stakeholders at our on-farm research site. The website of the Brian Nault Laboratory will be updated with results from year 1 of the project and general information on organic onion production, onion thrips, and *Stemphylium* leaf blight. There will be an international *Allium* symposium in Madison WI in July 2019, at which the team will have the opportunity to present research results to growers, processors, and researchers in the public and private sectors.

2018/09 TO 2019/08 Target Audience: The second year of the project continued to be focused on field research on our research farm, but also included research on two organic farms. Additionally, we held a field day on August 15th at Cornell AgriTech to show onion growers, University Extension educators and faculty, and the public our progress. The field day was advertised by NOFA-NY and was titled "Organic management of onion thrips and *Stemphylium* leaf blight in onion". Efforts to transfer knowledge about our research results will continue early next year. Changes/Problems: None What opportunities for training and professional development has the project provided? The project involved mentoring a postdoctoral researcher who continues to focus on this research as a major component of her appointment. She organized a workshop that was scheduled to be held at NOFA-NY's winter meeting in early January 2019, but the workshop was cancelled due to a catastrophic snow storm. She presented first-year results of our project at the Eastern Branch Meeting of the Entomological Society of America (EB-ESA) in March 2019 and results from first and second years of the project at the Entomological

Society of America Annual Meeting in November 2019. She also organized and presented results from both years of the project at the NOFA-NY Organic onion field day in August 2019. This experience continues to provide her with opportunities in professional development and science communication opportunity. Also, both high school and undergraduate student workers gained field experience examining the efficacy of insecticides and crop maintenance. This project supported a graduate student at University of Wisconsin who completed evaluations for pink root and Fusarium resistances in semi-glossy selections from the USDA onion breeding program. An undergraduate worker gained field experience with seed and bulb production of onion. How have the results been disseminated to communities of interest?The objectives of the project and research progress have been disseminated to onion growers, University Extension educators and faculty, and the public. Efforts to transfer knowledge about our research occurred primarily at the field day, research field sites during site visits. Additional conference and Extension presentations, field visits, and workshops will occur next year. What do you plan to do during the next reporting period to accomplish the goals?Research plans for next reporting period include repeating the experiments in onion grower's fields. These experiments combine the best OMRI-listed products and thrips-resistant onion varieties for managing onion thrips and Stemphylium leaf blight in onions. Results of the project will be shared at the Northeast Organic Farmers Association of New York (NOFA-NY) Annual Winter Conference in January 2020 and the Eastern Branch Meeting of the Entomological Society of America in March 2020. A field day will also be planned for the summer of 2020 with NOFA-NY to share the results of the research project to our stakeholders at our on-farm research site. The website of the Brian Nault Laboratory will be updated with results from both years of the project and general information on organic onion production, onion thrips, and stemphylium leaf blight.

2019/09 TO 2020/08 Target Audience:The third year of the project focused on research on two organic farms in NY and one in WI. Additionally, we held a workshop at the 2020 NOFA-NY Winter Conference in January 2019 in Syracuse, NY titled "Updates on Organic Onion Pest and Disease Management". Efforts to transfer knowledge about our research results will continue early next year. We had intended to repeat one field experiment on our research farm and hold another field day on at Cornell AgriTech to show onion growers, University Extension educators and faculty, and the public our progress, but due to the COVID-19 pandemic, research and extension activities were cancelled on the research farm. Changes/Problems:The onset of the COVID-19 pandemic resulted in major unexpected challenges for the 2020 research season. Research trials were reduced by 70%, which included cancelling our plans to repeat objective 1 cultural control trial for a third year. COVID limited undergraduate and graduate student workers for assisting with field work.COVID-19 also resulted in a cancellation of our annual 2020 field day in cooperation with NOFA-NY. Although the NOFA-NY 2021 Winter Conference will be held virtually, the number of workshops was reduced so significantly, that we were unable to secure a spot for this year. What opportunities for training and professional development has the project provided?The project involved mentoring a postdoctoral researcher who continues to focus on this research as a major component of her appointment. She presented results from the first and second years of the project at the Entomological Society of America Annual Meeting in November 2019 and 2020 and a CCE workshop in 2019. She also organized and presented results from both years of the project at the NOFA-NY Organic Winter Conference in Jan 2020. She has also published articles in major onion commodity and extension magazines with results from the first two years of the project. When she works in the field, she works closely with growers and provides updates on the projects during her visits. This experience continues to provide her with opportunities in professional development and science communication opportunity. How have the results been disseminated to communities of interest?The objectives of the project and research progress have been disseminated to onion growers, University Extension educators and faculty, and the public. Efforts to transfer knowledge about our research occurred primarily at the NOFA-NY Winter Conference, CCE Ag In-Service workshop, professional conferences, outreach publications, and research field sites during site visits. Due to the COVID-19 pandemic, we were unable to conduct our annual field day in 2020. Additional conference and Extension presentations, field visits, and workshops will occur next year. What do you plan to do during the next reporting period to accomplish the goals?Research plans for next reporting period include repeating the experiment on action-threshold levels in onion grower's fields. This experiment tests three different thresholds for onion thrips in combination with the best suite of OMRI-listed products and thrips-resistant onion varieties for managing onion thrips and Stemphylium leaf blight in onions. Results of the project will be shared at the Eastern Branch Meeting of the Entomological Society of America in March 2021. An e-Organic eXtension article is planned that focuses on onion thrips biology and organic management. Three articles summarizing the findings of our project will be submitted for publication in 2021. One is currently accepted and two others are in preparation. A field day will also be planned for the summer of 2021 with NOFA-NY to share the results of the research project to our stakeholders at our on-farm research site. The website of the Brian Nault Laboratory will be updated with results from both years of the project and general information on organic onion production, onion thrips, and stemphylium leaf blight.

## IMPACT

2017/09 TO 2018/08 What was accomplished under these goals? Objective 1: OMRI Thrips Trial (NY) - Nault OMRI-listed insecticides (4) and adjuvants (3) were evaluated for their combined effect on thrips and yield of 'Bradley' onions at a Cornell AgriTech research farm in Geneva, NY. The insecticides evaluated were spinosad, azadirachtin, azadirachtin + pyrethrin, and *Isaria fumosorosea* and an untreated control. The adjuvants were potassium (K) salts of fatty acids, neem oil, or terpene polymers. Applications were made weekly for 7 weeks and replicated 4 times. In situ counts of immature thrips were collected on 15 plants/plot each week. Onions were graded into four size classes (colossal, jumbo, standard, and boiler) for collecting yield data. Entrust co-applied with either M-Pede or Trilogy was the most effective insecticide + adjuvant combination for managing onion thrips in our trial. However, the combination of Entrust with these adjuvants did not have a similar benefit on onion yield. Neemix and PFR-97 co-applied with NuFilm provided some control of onion thrips; however, only Neemix had yields similar to Entrust. The use of Entrust with either M-Pede or Trilogy rotated with Neemix + NuFilm may be used effectively for onion thrips management in organic systems while maintaining resistance management programs. These products will be included in on-farm experiments in subsequent years of this project. OMRI Thrips Trial (WI) - Groves This trial was conducted at Crossroads Community Farm, WI. Four replicates of 16 foliar treatments and one untreated control were arranged in a RCBD. Each three-row plot measured 6 ft wide by 12 ft long. There were three weekly foliar applications applied with a CO<sub>2</sub>-pressurized backpack sprayer equipped with a four-nozzle 6-ft-wide boom fitted with flat-fan nozzles. Post-treatment thrips counts were obtained by counting the total number of thrips on 5 randomly selected plants from within each plot 2, 9, 14, and 21 days after first application (DAT). On 2 and 9 DAT, there were no differences in the number of thrips/plant. On 14 DAT, Entrust+M-Pede had significantly fewer thrips/plant compared to Venerate XC (2 qt/a) +NuFilm, Neemix+Trilogy, Azera+M-Pede, Azera+Trilogy, PFR-97 (2 lb/a)+NuFilm (8 fl oz/a), and the untreated control. There were no differences on 21 DAT. Examining the total number of thrips counts/plant over the season, Entrust+M-Pede had significantly fewer thrips than all other treatments except the other two Entrust treatments (Entrust+Trilogy and Entrust+NuFilm), and the two Venerate treatments co-applied with Neemix (Venerate XC (1 qt/a)+Neemix+NuFilm and Venerate XC (2 qt/a)+Neemix + NuFilm). The addition of M-Pede with Entrust numerically reduced the number of thrips/plant than the addition of NuFilm or Trilogy, which is similar to what was found in NY. OMRI SLB Trial (NY) - Hay, Pethybridge The trial consisted of 10 treatments (non-treated, eight OMRI listed products and one non OMRI-listed product) by three onion varieties (Ailsa Craig, Bradley and Avalon) arranged in a RCBD with four replicates of each treatment combination. The trial was located at the Cornell AgriTech, Geneva, NY. Applications of Entrust (8 fl oz/acre) and Trilogy (1%) were applied for thrips control on Jul 7 and Jul 13. Plants were inoculated with conidia of *S. vesicarium* on Jul 31 using a back-pack sprayer, with each plot receiving approximately  $2.1 \times 10^5$  conidia. Fungicide treatments were applied with the wetter Nufilm-P at 0.5 pints/ac at six times using a CO<sub>2</sub> back-pack sprayer equipped with a 38-in boom fitted with nozzles. Plots were assessed visually three times during the season for % leaf length blighted. On Oct 10, bulbs were graded by number and weight into boiler, standard, jumbo, colossal or cull size classes. Significant differences in *S. vesicarium* were apparent on 13 Sept with the non-OMRI listed product Oso, Badge X2, and Kocide 3000-O reducing disease compared to the control. On Sep 13, Bradley and Ailsa Craig had similar disease measurements, both significantly less than Avalon. This suggests Bradley may be less susceptible to SLB. Bradley has waxier leaves than Avalon, suggesting that leaf waxes are important in reducing SLB susceptibility. For fungicides other than Oso the mean incidence of *S. vesicarium* was high (>87.5%), irrespective of variety. However, for Oso, the mean incidence of *S. vesicarium* was high in Avalon (95.0%) and Ailsa Craig (82.5%), but substantially less in Bradley (62.5%). This suggested that the efficacy of Oso was higher when applied to a variety less susceptible to SLB. Despite differences in disease incidence and severity during the season, fungicide treatment had no significant effect on yield in comparison to the non-treated control. This suggested that none of the fungicide products were able to reduce *S. vesicarium* incidence or severity sufficiently to observe a yield response, or that factors other than SLB such as thrips pressure, were more important determinants of yield in this trial. In this trial, copper based products had some activity against SLB, and these are currently the only option for organic growers. Oso (FRAC 19) may also have a role in fungicide resistance management for conventional growers. Oso has labelled activity against several onion diseases including purple blotch, downy mildew, neck rot/leaf blight, and rust. Objective 2: This objective will be completed in years 2 and 3. Objective 3: Seed of an experimental hybrid (B5336AxB5351C) showing resistance to onion thrips for field evaluations. Inbreds W440 and W446 show resistance to the soil-borne diseases pink root and *Fusarium* basal rot; B5351 is susceptible to both diseases. W440 and W446 both have waxy foliage and are severely damaged by onion thrips; B5351 has semi-glossy foliage and suffers significantly less damage by onion thrips (Damon et al. 2014). Segregating F3 families were developed from the cross of W440 or W446 with B5351, and all families were screened for resistance to pink root and *Fusarium* basal rot. Families were also grown in the field and those

with semi-glossy foliage visually identified. In 2018, F3 progenies from two segregating families with semi-glossy foliage were intercrossed to increase seed. One of these families (24384) showed 74% FBR resistance, 77% PR resistance, and bulbs with excellent storage ability and no doubles. The second family (24604) showed 92% FBR resistance, 51% PR resistance, and had good bulb quality after storage. In 2019, seed of these increases will be provided to for thrips evaluations, and evaluated for amounts and types of epicuticular waxes at the University of Wisconsin. Additionally, 219 F3 progenies were self-pollinated to produce F4 families which will be screened for resistance to PR and FBR, as well as for foliage waxes. In 2019, bulbs will be harvested from families showing relatively high levels of resistance to both soil-borne diseases and semi-glossy foliage; these will be intercrossed in 2020 to produce elite onion populations with resistances to FBR, PR, and onion thrips. Cytoplasmic male-sterile plants will be included with these selections to develop male-sterile lines for eventual hybrid development. Seed will be provided for final thrips evaluations in 2021. Onion cultivars (Avalon, Bradley, Rossa di Milano, and Ailsa Craig with low and high wax controls) used by in spray trials in NY were grown in WI and sampled for GCMS analyses of leaf waxes. All GCMS runs have been completed, and data is being analyzed. Objective 4: We provided information about the ongoing field research to onion growers, University Extension educators and faculty, and the public. Efforts to transfer knowledge about our research occurred primarily at the research field sites. The laboratory website (B. Nault) was updated with information about the project objectives. We also trained a post-doc, undergraduate student and high school student during the reporting year (see section below). \*\*PUBLICATIONS (not previously reported):\*\* 2017/09 TO 2018/08 Type: Journal Articles Status: Accepted Year Published: 2019 Citation: Marzu, J. C., E. Straley, and M. J. Havey. 2019. Genetic analyses and mapping of pink-root resistance in onion. *J. Amer. Soc. Hort. Sci.* (submitted July 18, 2018; accepted October 23 2018)

2018/09 TO 2019/08 What was accomplished under these goals? Objective 1 In New York, several OMRI-listed insecticides were combined with three additional products (referred to as adjuvants) and evaluated for reducing onion thrips infestations and improving bulb yield at Cornell AgriTech. The insecticides evaluated were Entrust SC, Neemix 4.5, Azera and PFR-97. Each of these insecticides was combined with one of three adjuvants: M-Pede, Trilogy and NuFilm P. Applications were made weekly. Onions also were harvested and graded. Results were similar to those in 2018. The insecticide Entrust (spinosad) reduced overall season mean numbers of thrips more than any other insecticides evaluated in this study. The addition of M-Pede and Trilogy to Entrust reduced thrips densities more than the combination of Entrust and NuFilm. However, M-Pede caused some phytotoxicity when applied under sunny and hot conditions, so this product would need to be applied in the early hours of the day or at a reduced rate. None of the other insecticide and adjuvant combinations provided acceptable control of onion thrips. Onion yield was also affected by the insecticide treatment. Total onion yield was higher in the Entrust plots than the other insecticide treatments. Entrust (regardless of adjuvant) had a higher proportion of large onions (colossal and jumbo) compared with the other treatments. The results of the evaluation of OMRI-listed insecticides and adjuvants indicated that Entrust co-applied with either M-Pede or Trilogy was the most effective insecticide + adjuvant combination for managing onion thrips in organic onions and improving yield. Results of the 2019 field trial examining various OMRI-listed insecticides for thrips control in Wisconsin were not available in time for inclusion in this report. Similarly, a 2019 summary of the performance of OMRI-listed fungicides were not available to include in this report. In both cases; the trials were successful. In another field trial, two partially thrips resistant cultivars also were evaluated in 2018 and 2019, 'Rossa di Milano' and B5336 x B5351. Additionally, both were grown on either white on black or reflective mulch. Onions were either protected from thrips weekly with Entrust SC + Trilogy or were not protected from thrips. Fungicides were applied weekly to manage *Stemphylium* leaf blight. Rossa di Milano reduced onion thrips densities in both years, while B5336 x B5351 reduced densities only in 2018. Despite the differences in thrips control, B5336 x B5351 had significantly greater bulb yields than Rossa di Milano. Mulch had inconsistent significant effects on thrips densities and bulb yield was similar for both mulch types. Entrust + Trilogy provided excellent control of onion thrips, which translated to significantly greater bulb yields than untreated plots. Objective 2 Results from the on-farm trials that combined the best OMRI-listed insecticides and fungicides for onion thrips and *Stemphylium* leaf blight management have not been summarized, but the trials were successful. Objective 3 In 2019, bulbs of 'B5336 x B5351' were harvested from families showing relatively high levels of resistance to both soil-borne diseases and semi-glossy foliage; these will be intercrossed in 2020 to produce elite onion populations with resistances to *Fusarium* basal rot, pink root, and onion thrips. Cytoplasmic male-sterile plants will be included with these selections to develop male-sterile lines for eventual hybrid development. Seed will be provided for final thrips evaluations in 2021. Objective 4: We provided information about this project to onion growers, University Extension educators and faculty, and the public via an article in *Onion World* (most popular trade magazine for onion growers), a field day in New York and two professional entomological meetings. \*\*PUBLICATIONS (not previously reported):\*\* 2018/09 TO 2019/08 1. Type: Other Status: Published Year Published: 2019 Citation: Iglesias, L. and B. Nault. 2019. Tackling thrips in organic onions. *Onion World* 35(5): 7-9. 2. Type: Conference Papers and Presentations Status: Other Year Published: 2019 Citation: Iglesias, L., and B. A. Nault. 2019. Host-plant resistance and plastic mulches: Potential for managing onion thrips (*Thrips tabaci*) in organic onion production. *Entomological Society of*

America Annual Meeting, November 20, 2019, St. Louis, MO. 3. Type: Conference Papers and Presentations Status: Other Year Published: 2019 Citation: Iglesias, L., and B. Nault. 2019. Integrated approaches for managing onion thrips, *Thrips tabaci*, in organic onions. In: Breaking Ground: Research Highlights from ECPs and non-Academic Track Eastern Branch Members. Entomological Society of America's Eastern Branch meeting. Blacksburg, VA. March 11, 2019. 4. Type: Conference Papers and Presentations Status: Other Year Published: 2019 Citation: Iglesias, L., F. Hay and B. A. Nault. 2019. New tools for managing onion thrips and foliar disease in organic onion production. NOFA-NY Field Day at Cornell AgriTech, August 15, 2019, Geneva, NY.

2019/09 TO 2020/08 What was accomplished under these goals? Objective 1 Objective 1 consisted of two projects: 1) to evaluate OMRI-Listed bioinsecticides in combination with different adjuvants and 2) to evaluate plastic mulches and resistant cultivars in combination with bioinsecticides to manage onion thrips. Both of these trials were completed in 2019. Objective 2 The on-farm trials were conducted on two and one organic farms in NY and WI, respectively. Results from these trials that combined the best OMRI-listed insecticides and fungicides for onion thrips and *Stemphylium* leaf blight management have not been summarized, but the trials were successful. Objective 3 In 2019, bulbs of 'B5336 x B5351' were harvested from families showing relatively high levels of resistance to both soil-borne diseases and semi-glossy foliage; these were intercrossed in 2020 to produce elite onion populations with resistances to *Fusarium* basal rot, pink root, and onion thrips. Cytoplasmic male-sterile plants will be included with these selections to develop male-sterile lines for eventual hybrid development. Seed will be provided for final thrips evaluations in 2021. Objective 4: We provided information about this project to onion growers, University Extension educators and faculty, and the public via an article in *Onion World* (most popular trade magazine for onion growers), an article in the Cornell Cooperative Extension (CCE) *VegEdge* magazine, and presentations at the CCE Ag In-Service Training Meeting and two professional entomological meetings. \*\*PUBLICATIONS (not previously reported):\*\* 2019/09 TO 2020/08 1. Type: Journal Articles Status: Submitted Year Published: 2021 Citation: Havey, M.J., D.J. Hunsaker, and E.D. Munaiz. Genetic analysis of the unique epicuticular-wax profile of *Odourless Greenleaf* onion. *J. Amer. Soc. Hort. Sci.* 2. Type: Journal Articles Status: Accepted Year Published: 2020 Citation: Iglesias, L., R. L. Groves, B. Bradford, R. S. Harding, and B. A. Nault. Evaluating bioinsecticides for managing *Thrips tabaci* (Thysanoptera: Thripidae) in onion production systems. *Crop Prot.* 3. Type: Journal Articles Status: Published Year Published: 2020 Citation: Munaiz, E.D., P.A. Townsend, and M.J. Havey. 2020. Reflectance spectroscopy for non-destructive measurement and genetic analysis of amounts and types of epicuticular waxes on onion leaves. *Molecules* 25:3454. <https://doi.org/10.3390/molecules25153454> 4. Type: Journal Articles Status: Published Year Published: 2020 Citation: Khosa, J., D. Hunsaker, and M.J. Havey. 2020. Identities and phenotypic variation for epicuticular waxes among leaves and plants from inbred onion populations. *Hortscience* <https://doi.org/10.21273/HORTSCI115414-20> 5. Type: Journal Articles Status: Published Year Published: 2020 Citation: Munaiz, E.D. and M.J. Havey. 2020. Genetic analyses of epicuticular waxes associated with the glossy phenotype of *White Persian* onion. *J. Amer. Soc. Hort. Sci.* 145:67-72. <https://doi.org/10.21273/JASHS04840-19> 6. Type: Journal Articles Status: Published Year Published: 2020 Citation: Munaiz, E.D., R.L. Groves, and M.J. Havey. 2020b. Epicuticular leaf waxes among onion accessions selected for reduced damage by onion thrips. *J. Amer. Soc. Hort. Sci.* 145:30-35. <https://doi.org/10.21273/JASHS04773-19> 7. Type: Other Status: Published Year Published: 2020 Citation: Iglesias, L., and B. Nault. 2020. Bioinsecticides and cultural controls for onion thrips in organic onions. *VegEdge*, 16(11): 5-7. \*\* \*\*

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# Developing Multi-use Naked Barley for Organic Farming Systems

<b>Accession No.</b>	1013076
<b>Project No.</b>	ORE00253
<b>Agency</b>	NIFA ORE\
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26809
<b>Proposal No.</b>	2017-02470
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2020
<b>Grant Amount</b>	\$1,995,665
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Hayes, P.

## NON-TECHNICAL SUMMARY

Organic growers need new crops, markets, and rotation options supported by varieties that are developed specifically for organic conditions. Our long-term goal is to provide organic gardeners, growers, processors, and consumers with an alternative crop, food, and raw material that will be economically rewarding and sustainable. Currently, organic barley end-uses and markets are stratified due the presence of an adhering hull and grain  $\beta$ -glucan content. We will breed for naked barley and a modest level of  $\beta$ -glucan to create varieties suitable for brewing, feed use, and that will meet FDA guidelines for soluble fiber in human diets. Development, assessment, and participatory breeding of naked multi-use barley will be conducted in five representative regions/states - Pacific Northwest (OR, WA), Upper Midwest (MN, WI) and North East (NY) - using three classes of germplasm: a composite targeted to K-12 students and gardeners, a large diversity panel to apply genetic data to improve barley for organic systems, and a multi-regional trial to identify varieties for release. We will assess germplasm under organic conditions in school and home gardens, university research stations, and on-farm trials. We will evaluate agronomic, food, feed, malting, and brewing performance. Workshops will educate stakeholders on best management practices and processing procedures. We will quantify the economic and environmental benefits of organic naked barley production and products. Our outreach efforts will familiarize students, gardeners, growers, processors, and consumers with the benefits of naked barley varieties and provide guidance for capitalizing on the advantages these varieties can offer.

## OBJECTIVES

The long-term goals of this multi-region, integrative project are to: (1) provide organic growers, processors, and consumers with a new crop, food, and raw material alternative that will be economically rewarding and sustainable (2) identify and release high-yielding, high-quality, flavorful and nutritious multi-use naked barley varieties for organic systems based on a regional variety testing program anchored in Oregon, Washington, Wisconsin, Minnesota, and New York; (3) characterize key agronomic and food, feed, and malt quality traits in a large, genetically diverse panel of naked barley germplasm grown under organic conditions and maximize the efficiency of selection in this panel via integration of phenotypic and genotypic data; (4) observe, analyze, and report the results of natural selection and artificial selection on an organically grown naked barley composite population - a vehicle for engaging K-12 students and home gardeners in organic grains and foods; (5) understand the economic and environmental benefits of domestic organic naked barley production, and; (6) educate the public on the uses and production value of naked barley using a number of dissemination techniques.

## APPROACH

**Naked Barley Composite:** Seed samples will be provided free of charge to cooperating lead schools in the participating states. Students will collect data on the control and selected plots throughout the barley growing season. In addition, lead teachers will post descriptions and images of ongoing activities at the project website. At each lead school, outreach, plant breeding, and graduate student personnel will be available for visits throughout the season and each school will be partnered with a chef for a culinary experience. OSU will provide seed stock to interested seed companies for them to propagate and offer as organic seed in their catalogs. Purchasers will be invited to contribute observations and experiences and these will be posted at the project website - an informal "crowd science" approach to organic grains breeding.

**Regional Trial:** Fall-planted and spring trials will consist of existing varieties, advanced lines, and covered checks. They will be grown at 18 locations across five states. In each state, trials will be conducted on-farm and on-station. At each location, a three replicate Randomized Complete Block will be used. Standard yield trial protocols will be used at each location. Soil tests will be conducted at each location and organic fertilizer(s) applied as appropriate. Each variety will be evaluated for agronomic traits, measured using standard units at all locations. Winter trials will be evaluated for winter survival. Locally-occurring diseases will be rated using standardized rating scales. Weed Competitive Ability (WCA) will be measured using early vigor scores, early season height, and stand counts. Each variety will be evaluated for food quality traits. Micromalts and malt analysis will be made and performed on all lines. Sensory and flavor traits for food, malt, and beer will be measured on a selected subset of entries and environments. These abundant data will be used for in-depth analysis of genotype performance, genotype × environment interaction, and genotype × production system interactions.

**Diversity Panel:** The diversity panel will consist of 382 naked entries and covered checks. Entries will include winter, facultative, and spring growth habits, different seed coat colors, waxy and non-waxy starch, and lines with mostly unknown end-use properties. This ensures abundant genetic diversity to select for target traits in organic environments, but sufficient disease resistance, straw strength, and resistance to shattering so as to offer the possibility of direct release as a variety or at least as a parent in crosses designed to produce varieties. Trials will be conducted on-station under certified-organic conditions. Soil tests will be conducted at each location and organic fertilizer(s) applied as necessary to approximate crop nutrient needs. Manual weed control will be used as necessary. Each entry in the panel at each location will be evaluated for traits described for the regional trial at each location. All entries in the Diversity Panel will be genotyped using the Illumina 50K SNP Chip. The Diversity Panel will generate a rich data set with which to investigate key questions about effectively handling genetic diversity for organic systems and will allow us to address genotype × environment interaction for productivity, resistance, and grain quality traits. The multi-location/multi-trait assessments will allow for comparison of alternative selection indices for each location and subsets of locations. The application of marker assisted selection and selection of parents for crossing will be the focus of sustained and thorough participant discussion and consensus. This will provide important insight into how this nationally coordinated public breeding effort can share and utilize data sets to optimize breeding gains.

**Commercial production:** The on-farm commercial scale trials will be conducted in each of the five states. There will be commercial production (minimum 1 acre expected to produce at least 2,000 kg of grain) of at least one variety in each of the five states in at least two years. Streaker and Buck are the two winter types. The spring varieties will be provided by the Washington State University program (e.g. Havener) and the University of Minnesota program (variety release under consideration). Growers will be provided with certified seed at no charge. Participating processors/users (e.g. millers, bakers, maltsters, brewers and feeders) will buy the grain at current market prices. Grain will be milled by cooperating regional millers. Food products will include risen breads made with composite barley/wheat flours, steamed and boiled grains, and tortillas. Pilot malts will be made at the Barley World malthouse at OSU and with cooperators at Rahr Malting and Great Western Malting. Larger batch malts will be arranged between growers and commercial maltsters to produce sufficient malt for commercial brews at participating breweries. The performance and sensory attributes of two naked barleys and a traditional covered barley will be compared using lauter tun and mash filtration technologies in the OSU pilot research brewery. The feeding trial will assess egg and broiler production using Buck barley. For the egg trial, there will be three diets. The layer trial will involve a total of 90 birds with 30 birds per each of three replications. The egg trial will involve a total of 300 birds with 75 birds per each of three replications. The parameters measured for the egg trial will be mortality, bird body weight, egg number (daily) and egg quality. In the broiler trial, mortality and body weight (at three and six weeks) will be measured.

GrowNYC will begin to lay the groundwork for the barley market in the Northeast by engaging stakeholders and educating end users on the attributes of varieties that will be developed. Surveys on supply, demand, and sources for high quality organic feed will be conducted in year one. Two culinary events will be held in New York City, targeting taste leaders from the city's vibrant culinary community that is committed to developing organic agriculture and foods. Funds from the project will also go towards supporting educational staff at GrowNYC's Grainstand, at the Union Square Greenmarket, where hundreds of thousands of consumers shop on a weekly basis. In conjunction with these commercialization studies, Dr. Brian

Baker will conduct an assessment of the feasibility of the commercial adoption of the varieties through a combination of an on-line survey followed by telephone interviews of farmers. The survey will cover the perceived benefits, target markets, barriers to adoption, and the diffusion through seed distribution channels. **\*\*FINAL REPORT\*\*** 09/01/17 to 08/31/21 **\*\*Outputs\*\*** Target Audience: Public outreach efforts for naked organic barley included speaking at virtual and in-person organic agriculture and grain-related conferences, workshops, and events. Such events have allowed us to engage a diverse audience about the potential use of naked organic barley. Additionally, digital material produced after in-person gatherings became unsafe has allowed us to reach an even broader audience. Producers/growers End-users Processors Grain retailers and wholesalers Millers Brewers Distillers Maltsters Organic poultry egg and meat producers Animal feed suppliers and feed mills Chefs Bakers Students K-12 students Undergrad and graduate students Urban agriculture students Academic and industry researchers Organic organizations General Public Instagram/Facebook viewers (733 followers, 114 posts on \@nakedbarley) Consumers and farmers market shoppers Business owners Changes/Problems: Covid-19 related Problem: Visits and experiments with K-12 schools could not be conducted as planned. Solution: Planned activities were canceled and were moved online for the 2020-2021 school year. Problem: We could not hold our 2021 annual meeting with stakeholders in NY. Solution: Researchers began meeting virtually every month with each other and stakeholders and are working on developing other virtual content to disseminate to stakeholders. Researchers held a 2-hour virtual meeting in May 2021 to gather the entire group for annual updates. Problem: Because of University restrictions placed on hiring summer labor, several of the programs were not able to employ hourly workers to help with research. Solution: Trials were maintained and analyzed to the best ability of the current employees. Problem: Social distancing and other restriction prevented a large gathering of people for field days at UW-Madison. Solution: A smaller, more informal event was held instead with specifically invited guests. Not Covid-19 related Problem: Weather and pests resulted in quality issues and missed planting opportunities. Solution: For harvested grain with quality issues (primarily pre-harvest sprouting as a result of rain prior to harvest), we have an opportunity to look at the different responses of the lines in the trial, which gives us useful breeding and selection information. Problem: As a result of equipment break-downs, poorly germinating grain, and crop failure, the grain for the malting and brewing trials was rendered unusable. Solution: The malting and brewing study is underway, but will be completed in the fall of 2021. Problem: Lines in the diversity panel were found to be genetically identical despite having separate names and coming from different sources. This presents challenges in performing GWAS and GS analysis. Solution: Genetically identical lines that displayed the same phenotype were relabeled to have the same name. Lines that were similar, but not completely identical were removed from the following analyses. Problem: Covered lines used as replicated checks in the diversity panel do not have variability for threshability. This is detrimental when calculating means of replicated lines, because there is not a good estimation of experimental error for threshability based on the replicated hulled lines. Solution: The hulled lines were removed from the analysis for threshability and the genetically identical lines previously mentioned were used as replicated checks instead. Problem: Shortage of grain for GrowNYC Grains to work with and market at the Grainstand. Solution: Activities pivoted to outreach to farmers. Progress was made with Small Valley Milling producing several varieties on a commercial scale in 2020. Outreach may yield future results in building general capacity for handling. Problem: Preharvest sprouting and smut damage at more than one location in more than one year made statistical analyses of the quality data challenging. Solution: As a result of withdrawal of the damaged samples from the data set either post-hoc (PHS) or prior to testing (smut) the design became unbalanced and did not allow a full factorial analysis for many traits. What opportunities for training and professional development has the project provided? Indirectly, attendance at conferences conveying the benefits of organic naked barley has allowed for development of professional networks and provided input regarding breeding goals for naked organic barley. Discussion of ideas and challenges at these conferences and events has provided training in how the goals and execution of the project should go forward. The graduate students have had many opportunities for professional development and training. They have learned many technical skills regarding experimental design, field work, data analysis, food science, weed management practices, public speaking, as well as a good sense of what working in academia is like. Attendance at meetings, field days and other activities have provided many opportunities to learn new ideas and points of view. Field related activities also provide the chance to learn many hands-on skills including field and plot management. Also, graduate students funded by this grant were able to learn technical and academic skills that they would not have otherwise been exposed to. Chris Massman, Karl Kunze, and Cristiana Vallejos, the breeding graduate students working on this project have also had the opportunity to develop data analysis and academic paper writing skills. They have had the opportunity to learn and work with different genomic methods in plant breeding including GWAS and genomic selection. They have also gained experience in writing and submission of completed research. Additionally, from interactions at field days or conferences, they have begun to develop valuable networks with researchers and farmers. Through presenting research proposals and results at various functions, they have improved their speaking ability. The food quality analyses being run at OSU have provided opportunities to train a graduate student, Jordyn Bunting, and undergraduate in wet chemistry and other methods of analyzing flour and cooked grains. This has involved learning cereal quality

analytical and end-product testing and assessment, experimental design, statistical analyses, oral and written communication skills. Brigid Meints (former Postdoc, now Assistant Professor) has had the opportunity to mentor all of the graduate students on the grant and serves on the thesis committee for the OSU graduate student. This project has provided her training in project management, organizing events, malting, disease inoculation, and new data analysis techniques. GrowNYC Grains staff have been trained on the breeding process and culinary attributes of barley through this project. The GrowNYC Teaching Garden staff planted the Oregon Naked Barley Blend in their teaching garden and at the NYU Urban Farm Lab and learned about growing small-scale grain grow-outs. How have the results been disseminated to communities of interest? Details of the project have been disseminated through email, personal correspondence and communication, conferences, social media, and websites. UW-Madison, Cornell, and UMN hosted in-person field days and OSU hosted virtual field days on Instagram Live. The UW-Madison person field day was attended by approximately twenty growers and other people in industry. Because of the small size, researchers were able to engage participants more directly in the question-and-answer sections of the event. Social media postings in Instagram and Facebook allow researchers to share project updates and photos with thousands of followers between @nakedbarley, @culinarybreedingnetwork, @eorganicofficial, and @grownycgrains. Brigid Meints from OSU presented at the Craft Malt Conference on malting and brewing naked barley. June Russell, Brigid Meints, and Karl Kunze participated in a panel discussion with project partners at the Philadelphia Grain and Malt Symposium on Naked Barley and Other Value-Added Grains. Brigid Meints, Pat Hayes, Jordyn Bunting, and Cristiana Vallejos of Oregon State University gave a presentation on the Multi-use Naked Barley project at the Culinary Variety Showcase. Available at <https://youtu.be/60V62G8yREo?t=5531>. Karl Kunze of Cornell University presented an eOrganic webinar entitled Progress on Organic Naked Barley Breeding: Exploration of Organic Breeding Traits. Available at <https://youtu.be/oW0FjpbbsMo>. Brigid Meints and Andrew Ross participated in a barley workshop with Sarah Owens titled 'Bodacious Barley Workshop'. Researchers collaborated with a graphic designer to produce a barley zine, which includes information about the project and recipes developed by collaborators and stakeholders. A printed version has been distributed to 200 people and the digital version has reached hundreds more. Each of the breeding programs have uploaded phenotypic data from the regional trials and diversity panels to the T3 (Triticeae Toolbox: <https://triticeaetoolbox.org/barley/>) database. These data can be accessed by other breeding programs and researchers. Participants from this project teamed up with organizers of the Cascadia Grains Conference, and members of the Value-added Grains OREI project to host a week-long conference called 'Grains Week'. Five of the presentations (given by Brigid Meints, Cristiana Vallejos, Andrew Ross, Jordyn Bunting, Mark Sorrells, Julie Dawson, June Russell, Kevin Smith, and Pat Hayes) focused specifically on this project; the total view for the week were 5,403. This content is on YouTube and may garner further views in the future. Chris Massman presented regional trial results from the first cycle of the grant to CIAS faculty in October of 2021. The presentation was online and attended by approximately twelve people. A question-and-answer session followed the presentation. Chris Massman presented regional trial and diversity panel results from the first cycle of the grant to plant breeding and plant genetics students and faculty at UW Madison. The presentation was online and attended by approximately thirty people. A question-and-answer session followed the presentation. In collaboration with Portland-based Wellspent Market (retail, wholesale and online store), Barleyworld and Culinary Breeding Network promoted barley and barley products (whole grain and flakes) and a giveaway during Grains Week. Wellspent started offering locally grown, organic 'Streaker' barley flakes as a result of collaboration. Wellspent owner Jim Dixon and CBN director Lane Selman executed an Instagram live (1272 views) to discuss using barley in the kitchen. Wellspent created and promoted barley recipes thru social media and their website -recipeandcookie recipe. In collaboration with Portland-based pastamaker Emily Park, offered barley pasta kits for sale during Grains Week. In collaboration with PNW chain Burgerville (40 locations in WA and OR) organic hull-less barley has been included in their new "Seedlings" program. 'Purple Karma' barley is being distributed in kids meals at each location. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported \*\*Impacts\*\* What was accomplished under these goals? In the final year of the grant, participants worked on conducting end-use quality tests and analyzing data from over 400 naked barley lines grown in certified organic trials during the first three years of the project, characterizing them for agronomic traits, food and malt quality traits, weed competitive ability, and resistance to abiotic and biotic stressors. These analyses include characterizing the genotype by environment interactions for agronomics and food quality of naked barley germplasm as well as investigating the genetic basis of threshability, weed competitive ability, and resistance to a range of diseases. Understanding these characteristics allows breeders to make optimal decisions for selecting the best barley variety in their region. With the results of these trials, we have begun new breeding work to select for traits necessary for organic production. Journal and extension publications are in preparation to disseminate the results of these experiments to researchers and growers. Survey and interview results looking at the economic feasibility of growing organic barley have been published and will continue to be made available to growers. Hundreds of growers, processors, and consumers have been provided with trial results and information about naked organic barley at conferences, virtual field days, through personal communication, website postings, and social media. Goal 1: The value of

naked barley as a new potential crop was described to stakeholders through a variety of mechanisms. In MN, a six-acre grain increase of MS10S4111-01, an advanced breeding line, were conducted for large-scale end-use testing and distribution to interested end-users. At UW-Madison, sensory analysis on food grade naked barley was performed with professional bakers. Bakers worked with flour from different naked lines to replicate a sugar cookie recipe and a pita recipe. Baked goods were then sampled by customers and other researchers in a blind taste test. Researchers at UW-Madison convened a discussion of key stakeholders, including farmers, bakers, millers and seed company representatives to share these results. Goal 2: Data analyses, including ANOVAs, correlations, and mean separations have been performed on agronomic data from the regional trials. A combined analysis of regional trial data from all three seasons was performed to assess lines in the panel as well as determine the observed variance attributable to genetic, environmental and genotype by environmental effects. A variety of methods was used including ANOVA, Spearman correlations between genotypic rankings in each environment, GGE models, and random effects models. This agronomic yield trial data is being analyzed to identify regions where genotypes perform similarly, also known as mega-environments. This information will allow breeders to tailor selections to the regional level and allow the best possible genotypes to be released to growers. A Finlay-Wilkinson analysis has also been used to identify genotypes that show high or low sensitivity to their environment. Results from these analyses are being prepared in a manuscript for publication. Key food quality traits have been characterized on the regional trials. Samples of spring, winter, and facultative barley from Corvallis OR, Freeville NY, Madison WI, and Arlington WI over three harvest years (2018, 2019, and 2020) were tested for moisture, kernel hardness, beta-glucan levels, and multiple components of flour/starch pasting properties. In addition, 450 of the above samples were subjected to extended testing that encompassed protein, flour water absorption, flour/water batter flow properties, cooked grain texture (hot and cold), and cooked grain yields. Color was quantified on grain, whole-grain flour, and cooked wholegrains from these samples using a tristimulus color meter. Investigations targeted the efficiency of breeding selection via integration of phenotypic and genotypic data and statistical analyses. Statistical analysis may lead to the identification of a small number of key food traits that can categorize naked barley, aid in breeding selections, and aid buyers and processors in identifying the correct type of organic naked barley for their specific end-use. Goal 3: Analysis of data from all three years of diversity panel grow-outs was conducted. Preliminary analyses of genotyped lines in the diversity panel have been performed in preparation for GWAS and GS studies. This includes calculation of LD decay, PCA for genetic relationship between lines, and dendrograms for genetic relationship. Preliminary GWAS analysis has revealed significant hits for winter survival, maturity date, heading date, plant height, early plant vigor, stripe rust, and leaf rust. Threshability, or ease of hull loss, was identified as a key trait for naked grains in the first cycle of the grant. Grain failing to shed its hull loses the advantages of naked grains over covered grain. Despite its importance, there is not a large amount of published information on threshability. Using information from the diversity panel, research was done in the genetic basis and plausibility of genomic selection for threshability. The data set includes five environments where threshability was scored for 350 distinct barley genotypes. GWAS was performed to identify QTL with a significant association to threshability. Results from these analyses are being prepared in a manuscript for publishing. Goal 4: In-person classroom visits had to be cancelled as a result of Covid-19. However, researchers are continuing to work with teachers to find ways to provide distance learning and educational resources safely. K-12 teachers and project researchers are working together to transition lesson plans from in-person to virtual activities. Additionally, new lesson plans (<https://oregonaitc.org/lessonplan/the-f2-generation-of-buck-and-lightning/> and <https://oregonaitc.org/lessonplan/the-barley-family-observable-traits-of-barley/>) that meet curriculum standards for multiple grade levels were created that will have options for in-person or virtual learning. The Oregon Naked Barley Blend has been distributed to teachers and continues to be distributed to interested home gardeners for planting and selection. Goal 5: Our agriculture economist distributed a grower survey in 2019 regarding organic barley production. The results were written up in a journal article that was published in Organic Agriculture and an extension article that is available at eOrganic. Both publications are open access, so they are available to the target audience. Survey respondents were informed of the publications. Additionally, he prepared a short presentation for the 2021 Organic World Congress conference. Goal 6: Details of the project have been disseminated through email, personal correspondence and communication, virtual and in-person field days, virtual conferences, and websites. The eOrganic website is updated to reflect progress of the project and contains bulletins, publications, webinars, and social media accounts. Due to Covid-19, the 2021 Variety Showcase was moved online to YouTube. Four members of the group presented during a session that received 839 unique views. Additionally, participants from this project teamed up with organizers of the Cascadia Grains Conference, and members of the Value-added Grains OREI project to host a week-long conference called 'Grains Week'. Five of the presentations focused specifically on this project; the total view for the week were 5,403. This content is on YouTube and may garner further views in the future. Participants presented at the Virtual Craft Malt Conference, Virtual Philly Malt and Grain Symposium, Virtual 2020 National Scab Forum, and at various workshops and other events. Participants at OSU hosted two Instagram live field tours for a total of 294 views. Participants at UMN and UW-Madison were able to hold in-person field days. **\*\*Publications\*\*** - Type:

## PROGRESS

2017/09 TO 2018/08 Target Audience: Public outreach efforts for naked organic barley were speaking at regional field days, and discussion at organic and agricultural conferences. Such events have allowed us to engage a diverse audience about the potential use of naked organic barley. Growers Processors Brewers Business owners Maltsters General public K-12 students College students Chefs Bakers Academic and industry researchers Politicians Organic organizations Instagram viewers (281 followers, 41 posts) Changes/Problems: Problem: A lack of suitable certified organic land for our regional test plots and seed increases. In some cases, the certified organic land had not been in a long-term rotation necessary to establish proper soil health. In other cases, seed increases had to be conducted on research farms due to a lack of local organic farmers. Solution: We are implementing rotations and developing a network with organic farmers who are interested in hosting trials. Problem: A complicating factor in outreach is working with business owners (producers, bakers, and brewers) who have limited time and resources to devote to experimentation and risk-taking. Events and outreach must be scheduled to meet their timetables to ensure strong participation. As a result, considerable time is spent coordinating, which creates a lag in achieving outcomes. Solution: Effective communication and scheduling Problem: Many collaborators are new to organic research and struggled to achieve adequate weed control in the plots. Solution: Adjustments of planting dates and seeding rates, as well as weed control strategies, are being developed and will be implemented. Problem: Hiring delays. The postdoc was unable to officially start until January, the graduate student at UW-Madison did not start until June, and WSU did not get a graduate student during the first year. Solution: We have successfully worked through the first of these two personnel issues and are working with WSU to get a student. Problem: The number of trials planned did not meet the number specified in the grant (14 instead of 18 regional trials and 5 instead of 10 diversity panels), due to one or more of the following: lack of seed, lack of certified organic land, loss due winter kill, pre-harvest sprouting damage, or excessive weediness. Solution: Seed for all proposed trials will be distributed in the second year of the grant. Cold temperatures and early rains are out of our control; however, we can use these climate events to learn about our breeding material. What opportunities for training and professional development has the project provided? Indirectly, attendance at malting and organic conferences conveying the benefits of organic naked barley has allowed for development of professional networks and provided input regarding breeding goals for naked organic barley. Discussion of ideas and challenges at these conferences has provided training in how the goals and execution of the project should go forward. Additionally, at the annual project meeting, getting to meet collaborators of the project in person allowed for a faster exchange of ideas and challenges associated with the project. At UMN, they have one undergraduate student, who is beginning grad school this fall participating on the project. She is coordinating activities with area schools. At UW-Madison and Cornell, the graduate students have had many opportunities for professional development and training. They have learned many technical skills regarding field work as well as a good sense of what working in academia is like. Two WSU graduate students attended Barley Day at OSU in Corvallis, as well as the OREI project meeting, also in Corvallis. Though neither student is funded directly through this project, the meeting and field day were beneficial in broadening their barley horizons outside of the Palouse region, connecting with OSU barley scientists to learn about production and micro-malting equipment, procedures and opportunities. The Postdoc on the grant, Brigid Meints had the opportunity to mentor the graduate students on the grant as well as undergrads at OSU. She also spoke at several conferences and field days, as well as had the opportunity to plan the content of the project meeting and OSU Barley field day. How have the results been disseminated to communities of interest? Details of the project have been disseminated through email, personal correspondence and communication, field days at all universities, press releases, conferences, and websites. OSU hosted 'Barley Day 2018', which was a day-long field day focused on this project. It was held in conjunction with the annual project meeting and included collaborators from all states who gave presentations. 100 people attended, including brewers, chefs, bakers, growers, maltsters, processors, the general public, and college students. Data from the first-year field trials are still being collected and will be posted via email, field days, barleyworld.org, and on program websites. Additionally, there will be presentations at conferences of the data collected from the first year of growing naked organic barley. Kevin Smith from UMN made two presentations at a conference organized by the Practical Farmers of Iowa called Rotationally Raised - Making small grains rotations work. The audience was conventional and organic farmers. One presentation was on disease management and the other on breeding and varieties for the craft brewing industry. UW-Madison had several successful field days this summer. The organic, WCIA and Antigo field days have all drawn at least 20 people. Attendees were from various backgrounds and included seed dealers, growers, and end-users. Brigid Meints and Pat Hayes from OSU gave presentations about the project in OSU college classes, at the Culinary Breeding Network Variety Showcase, the Cascadia Grains Conference, the Organic Seed Growers Conference (breeding and culinary), the Student Organic Seed Symposium, the Public

Interest Environmental Law Conference, and an Olive Oil/Barley tasting event hosted by the Culinary Breeding Network. Lane Selman from OSU gave a presentation and helped put on a workshop at the Grain Gathering conference. What do you plan to do during the next reporting period to accomplish the goals? Use preliminary data and experiences as basis for discussing uses of naked organic barley at conferences that will reach organic farmers. Use data to select lines in regional trials that exhibit target levels of food and malting traits. Use local data regarding environment specific factors affecting yield such as disease resistance, lodging, heading date, weed competitive ability to identify drives of local and broad adaptation. Initiate new crosses and continue to select and advance cross progeny for variety development. Engage in more outreach events associated with organic farming to develop connections with organic farmers and to learn more about the challenges associated with organic farming. Engage in more outreach efforts regarding the uses of naked organic barley to various communities of interest. Release experimental black seed color breeding line 'BB99' from OSU; it performs well in organic systems. Develop spec sheets on functionality for bakers, maltsters, and feed operations for different varieties. Genotyping and analysis of the diversity panel will be conducted. Continue to observe natural and artificial selection at schools and with cooperators growing the Oregon Naked Barley Blend. Literature reviews on naked barley and on the economic and environmental impacts of naked barley will be written and submitted to peer-reviewed journals. Continue to educate our target audience through workshops and conferences (Variety Showcase NYC, Naked Barley workshop in NYC, Winter Squash and barley workshop, Cascadia Grains Conference, MOSES, Organicology, Slow Food Portland event, Noodle School, Bob's Red Mill classes, Barley Day, Grain Gathering, Student Organic Seed Symposium). Conduct the feed study with poultry extension specialist Jim Hermes at OSU. Continue regional and diversity panel trials with all collaborators. Conduct food and malt quality analysis on the grain harvested in 2018. The annual project/stakeholder review meeting will be held in the Midwest in 2019. Develop and implement two webinars with eOrganic. Gather and provide information on research and opportunities for growers, processors, bakers, and brewers to gain access to naked barley. Further outreach to feed suppliers and end users will be conducted to inform stakeholders about the project, assist in the development of the market, capture information on market potential and educate end users on the attributes of naked barley in feed rations. Conduct expanded outreach to professionals in the craft beverage and culinary sectors. Begin direct marketing Buck and #STRKR barley at the GrowNYC Greenmarket Grain's Grainstand in the fall of 2018.

2018/09 TO 2019/08 Target Audience: Public outreach efforts for naked organic barley included speaking at regional field days and at organic agriculture and grain-related conferences, workshops, and events. Such events have allowed us to engage a diverse audience about the potential use of naked organic barley. Producers End-users Processors Millers Brewers Distillers Maltsters Organic poultry egg and meat producers Nutritionists and feed manufacturers that formulate diets for poultry producers Chefs Bakers Students K-12 students Undergrad and graduate students Students of urban agriculture Academic and industry researchers Organic organizations General Public Instagram/Facebook viewers (391 followers, 68 posts) Consumers and farmers market shoppers Business owners Changes/Problems: Problem: WSU stepped back from most aspects of the project as a result of the barley breeder taking a new position and lack of personnel. Solution: We re-assigned two years of graduate student funding to bring on a master's student at OSU to focus on cereal quality. We re-focused the work in Pullman, WA to look at mineral analysis by XRF and beta-glucan and protein calibration by NIR and combustion, respectively. Because of this change, we are actually able to fund parts of four graduate student's work instead of three. Problem: Weather and pests resulted in quality issues and missed planting opportunities. Solution: For harvested grain with quality issues (primarily pre-harvest sprouting as a result of rain prior to harvest), we have an opportunity to look at the different responses of the lines in the trial, which gives us useful breeding and selection information. Problem: Throughout all the regional trials and diversity panels for the 2018-2019 field season, we saw a significant increase in loose and covered smut. In conventional systems, a fungicide treatment is applied to seeds to control smut. In organic systems, there are few effective cultural practices that are effective in reducing or eliminating smut. Solution: Breeding for smut resistance should be a top priority for organic naked barley. Problem: Trials had severe weed pressure that reduced data quality and seed amounts. Solution: Mechanical weeding was done between plots in the regional and diversity trials when plants were still small. Additional hand weeding was performed on a regular basis on following occasions. Problem: Seed yield at some locations was not high enough in the regional trial to perform baking or protein testing Solution: Plot size was doubled. This in conjunction with weeding efforts has highly increased seed yield. Problem: Protein levels in the 2018 harvest were so low that they were not able to be malted and brewed with as representative samples. Solution: The malting and brewing study was postponed until year three. What opportunities for training and professional development has the project provided? Indirectly, attendance at malting and organic conferences conveying the benefits of organic naked barley has allowed for development of professional networks and provided input regarding breeding goals for naked organic barley. Discussion of ideas and challenges at these conferences has provided training in how the goals and execution of the project should go forward. The samples used for nutritional analysis have provided the opportunity to train WSU graduate students and a Whitman

College undergraduate intern to use the NIR and XRF equipment. Most importantly, these samples have aided in the optimization of sample preparation and equipment calibration. Additionally, the food quality analyses being run at OSU have provided opportunities to train a graduate student in wet chemistry and other methods of analyzing flour. At UW-Madison and Cornell, the graduate students have had many opportunities for professional development and training. They have learned many technical skills regarding experimental design, field work, data analysis, food science, weed management practices, public speaking, as well as a good sense of what working in academia is like. Additionally, graduate student attendance at meetings, field days and other activities has provided many opportunities to learn new ideas and points of view. Meeting professors, students and members in industry at these events has allowed for many opportunities to learn and grow. The Postdoc on the grant, Brigid Meints had the opportunity to mentor all of the graduate students on the grant. She also spoke at several conferences and field days, as well as had the opportunity to plan the content of the project meeting and OSU Barley field day. She also attended a weeklong intensive course on quantitative genetics and statistical breeding to prepare for conducting GWAS analysis and implementing Genomic Selection. The poultry study allowed undergraduate students and a visiting international scholar to assist and provide input into with this research. How have the results been disseminated to communities of interest? Details of the project have been disseminated through email, personal correspondence and communication, field days at all universities, press releases, conferences, and websites. OSU hosted 'Barley Day 2019', which was a half-day field day focused on this project. Additionally, UW-Madison hosted an Organic Barley Field day that was held in conjunction with the annual project meeting and included collaborators from all states who gave presentations. 75 people attended, including growers, maltsters, processors, bakers, the general public, and college students. The other universities all held summer field days as well, where information about this project was shared with the general public. Brigid Meints from OSU gave presentations about the project with preliminary results in OSU college classes, regional field days, the Culinary Breeding Network Variety Showcase, the GrowNYC naked barley event, the Cascadia Grains Conference, the Organic Agricultural Research Forum, the Craft Maltsters Conference, Camp Camas, and the Student Organic Seed Symposium. Jim Hermes, the poultry extension specialist provided preliminary results at Barley Field Day, in June 2019. A publication on the results of the layer study is being prepared for submission. Results will be shared to various Extension and/or trade association audiences. Through meetings, field days and personal communication results have been disseminated to communities of interest. UW-Madison hosted the 2019 barley days and annual meeting. Over two days researchers, students, stakeholders and community members met and exchanged ideas and results. During year 2, Cornell collaborators have continued to speak about naked organic barley at regional field days (June 6, July 2, July 26), discuss progress of organic barley research at agricultural research conferences such as the tri-societies and the NY- NOFA (New York Northeast Organic Farming Alliance) seed symposium conference in January 2019. The team at UMN discussed research at a field day presentation at Crookston, MN on July 17; ~ 80 participants/farmers. June Russell of GrowNYC Grains presented on the marketing efforts of GrowNYC Grains at the Hudson Valley Grain School where she announced the Naked Barley Project to inform stakeholders of research and potential opportunities. The audience of approximately 100 attendees consisted of farmers, food and beverage professionals and other farm advocacy organizations. Additionally, she shared findings and reports on malting and naked barley performance from project team members at Brewers Choice in Brooklyn, NY and served on panel at Slow Grains, hosted by Slow Food NYC. What do you plan to do during the next reporting period to accomplish the goals? Scholarship Develop and implement two webinars with eOrganic. Submit publications to eOrganic and scientific journals about projects (GxE from regional trial, weed management, GWAS results, brewing trial, food quality analysis) from the grant. Release a paper characterizing lines in the regional trials for use in both the project's breeding efforts and in outreach to growers. Complete the egg production trial publication. Accomplish the broiler trial and publication. Report results to appropriate audiences as available. Education Continue to observe natural and artificial selection at schools and with cooperators growing the Oregon Naked Barley Blend. Host sixth graders from a local middle school in Madison, WI and use selection information from this year's experiments to demonstrate crosses and expose students to genetic/statistical concepts. Host middle schoolers in Oregon at our organic plots and discuss weed control, diseases, breeding and genetics, and end-uses of naked barley. Continue to engage elementary school students in New York and Minnesota in school gardens. Outreach Use preliminary data and experiences as basis for discussing uses of naked organic barley at conferences that will reach organic farmers. Engage in more outreach events associated with organic farming to develop connections with organic farmers and to learn more about the challenges associated with organic farming. Engage in more outreach efforts regarding the uses of naked organic barley to various communities of interest. Develop spec sheets on functionality for bakers, maltsters, and feed operations for different varieties. Continue to educate our target audience through workshops and conferences (Variety Showcase, Winter Squash and barley workshop, Cascadia Grains Conference, MOSES, Organic Seed Growers Conference, Barley Day, Student Organic Seed Symposium, Organic World Congress). Gather and provide information on research and opportunities for growers, processors, bakers, and brewers to gain access to naked barley. Further outreach to feed suppliers and end users will be conducted to inform stakeholders about the project, assist in the development of the market,

capture information on market potential and educate end users on the attributes of naked barley in feed rations. Conduct expanded outreach to professionals in the craft beverage and culinary sectors. Continue outreach and education on the project through staff engagement with farmers and other stakeholders. Increase education and outreach through social media channels, Facebook, Instagram, Flickr and the GrowNYC Grains newsletter. Host field days and other outreach events to increase community involvement and awareness. The annual project/stakeholder review meeting will be held in the Northeast in 2020. Research Use data to select lines in regional trials that exhibit target levels of food and malting traits. Use local data regarding environment specific factors affecting yield such as disease resistance, lodging, heading date, weed competitive ability to identify drives of local and broad adaptation. Initiate new crosses and continue to select and advance cross progeny for variety development. Conduct the broiler feed study with poultry extension specialist Jim Hermes at OSU. Continue regional and diversity panel trials with all collaborators. Conduct food and malt quality analysis on the grain harvested in 2019. Use the data from the diversity panel lines to investigate genes of interest in organic production. Grow Diversity lines in fully replicated plots in an unbalanced arrangement between locations to increase seed use efficiency and data quality. Use increased seed from the 2019 regional experiments to do more in depth testing and analysis including baking and quality trials. During the next reporting period, samples will be analyzed using a combustion method to determine protein to better calibrate the NIR.

2019/09 TO 2020/08 Target Audience: Public outreach efforts for naked organic barley included speaking at organic agriculture and grain-related conferences, workshops, and events. Such events have allowed us to engage a diverse audience about the potential use of naked organic barley. Additionally, digital material produced after in-person gatherings became dangerous has allowed us to reach an even broader audience. Producers End-users Processors Millers Brewers Distillers Maltsters Organic poultry egg and meat producers Chefs Bakers Students K-12 students Undergrad and graduate students Academic and industry researchers Organic organizations General Public Instagram/Facebook viewers (510 followers, 90 posts) Consumers and farmers market shoppers Business owners Changes/Problems: Covid related Problem: Field, office, greenhouse, and any outreach activities were limited in the spring and summer of 2020 due to the UW-Madison's health concerns related to Covid-19 and spring trials could not be planted. Solution: Fall trials already in the ground were maintained and data was recorded for the planted genotypes. The spring trial will be grown in 2021. Problem: Visits and experiments with K-12 schools could not be conducted as planned during the spring of 2020. Solution: Planned activities were canceled and will be moved online for the 2020-2021 school year. Problem: We could not hold our 2020 annual meeting with stakeholders in NY. Solution: Researchers began meeting virtually with each other and stakeholders and are working on developing other virtual content to disseminate to stakeholders Problem: In-person field days had to be cancelled. Solution: Virtual field days were held by the UW-Madison and Cornell teams. Problem: Because of University restrictions placed on hiring summer labor, several of the programs were not able to employ hourly workers to help with research. Solution: Trials were maintained and analyzed to the best ability of the current employees. Not Covid related Problem: At UW-Madison, a planter malfunction during planting of the fall panel led to uneven seed distribution in the first three columns. Solution: These lines were replanted at a later date adjacent to the original experiment. Problem: Weather and pests resulted in quality issues and missed planting opportunities. Solution: For harvested grain with quality issues (primarily pre-harvest sprouting as a result of rain prior to harvest), we have an opportunity to look at the different responses of the lines in the trial, which gives us useful breeding and selection information. Problem: As a result of equipment break-downs, the grain for the malting and brewing trials was rendered unusable. Solution: The malting and brewing study was postponed until the fall of 2020. What opportunities for training and professional development has the project provided? Indirectly, attendance at malting and organic conferences conveying the benefits of organic naked barley has allowed for development of professional networks and provided input regarding breeding goals for naked organic barley. Discussion of ideas and challenges at these conferences has provided training in how the goals and execution of the project should go forward. The graduate students have had many opportunities for professional development and training. They have learned many technical skills regarding experimental design, field work, data analysis, food science, weed management practices, public speaking, as well as a good sense of what working in academia is like. Attendance at meetings, field days and other activities have provided many opportunities to learn new ideas and points of view. Field related activities also provide the chance to learn many hands-on skills including field and plot management. Also, graduate students funded by this grant were able to learn technical and academic skills that they would not have otherwise been exposed to. Chris Massman and Karl Kunze, the breeding graduate students working on this project have also had the opportunity to develop data analysis and academic paper writing skills. Additionally, from interactions at field days or conferences, they have begun to develop valuable networks with researchers and farmers. Through presenting research proposals and results at various functions, they have improved their speaking ability. The food quality analyses being run at OSU have provided opportunities to train a graduate student, Jordyn Bunting, and undergraduate in wet chemistry and other methods of analyzing flour and cooked grains. There has also been opportunities for Jordyn to practice public speaking, data analysis, and product

development. The Postdoc on the grant, Brigid Meints has had the opportunity to mentor all of the graduate students on the grant and serves on the thesis committee for the OSU graduate student. This project has provided her training in project management, organizing events, malting, disease inoculation, and new data analysis techniques. GrowNYC Grains staff have been trained on the breeding process and culinary attributes of barley through this project. The GrowNYC Teaching Garden staff planted the Oregon Naked Barley Blend in their teaching garden and at the NYU Urban Farm Lab and learned about growing small-scale grain grow-outs. How have the results been disseminated to communities of interest? Details of the project have been disseminated through email, personal correspondence and communication, conferences, social media, and websites. UW-Madison and Cornell hosted virtual field days in place of in-person events. UW-Madison produced a video of the fall regional trial to show to local producers and growers. This video was also used as the basis of a forum for local organic producers and people in industry to talk about naked barley and the work occurring with the naked barley project. Social media postings in Instagram and Facebook allow researchers to share project updates and photos with hundreds of followers. Brigid Meints from OSU gave presentations about the project with preliminary results and hosted tastings in OSU seminar classes, the Culinary Breeding Network Variety Showcase, the Organic Seed Growers Conference, Tuality Plains Great Grains Event, and the University of Colorado, Colorado Springs Grain School. These presentations reached nearly 1000 people, including college students, growers, bakers, chefs, millers, processors, and the general public. A seminar on naked barley research was presented by Chris Massman to faculty and students in the UW-Madison PBPG program. A poster presentation was also given by Chris at the MOSES organic conference to present findings from the regional trials. Jordyn Bunting from OSU presented on his research at the Winter Vegetable Sagra, the Cascadia Grains Conference, and in an OSU seminar class. Researchers collaborated with a graphic designer to produce a barley zine, which includes information about the project and recipes developed by collaborators and stakeholders. A printed version has been distributed to 200 people and the digital version has reached hundreds more. Each of the breeding programs have uploaded phenotypic data from the regional trials and diversity panels to the T3 (Triticeae Toolbox: <https://triticeaetoolbox.org/barley/>) database. These data can be accessed by other breeding programs and researchers. June Russell of GrowNYC Grains presented on the marketing efforts of GrowNYC Grains at the Hudson Valley Grain School where she announced the Naked Barley Project to inform stakeholders of research and potential opportunities. The audience of approximately 100 attendees consisted of farmers, food and beverage professionals and other farm advocacy organizations. Additionally, she shared findings and reports on malting and naked barley performance at the Cascadia Grains Conference. Additionally, through sales at the GrowNYC Grainstand, GrowNYC staff have been able to disseminate information about the project to thousands of consumers. Through their newsletter and social media accounts, which have featured this project on numerous occasions, they have reached thousands more. What do you plan to do during the next reporting period to accomplish the goals? Scholarship Develop and implement two webinars with eOrganic. Submit publications to eOrganic and scientific journals about projects (GxE from regional trials, weed management, GWAS results, brewing trial, food quality analysis) from the grant. Release a paper characterizing lines in the regional trials for use in both the project's breeding efforts and in outreach to growers. Complete the layer and broiler trial publications. Report results to appropriate audiences as available. Education Host (virtually) sixth graders from a local middle school in Madison and use selection information from this year's experiments to demonstrate crosses and expose students to genetic/statistical concepts. Work with teachers at the local schools to reach out to students safely as they move to a distance learning model in the fall. Provide seed and teaching resources for students to perform their own experiments at home. Develop virtual lesson plans for a variety of curriculum standards and grades Outreach Develop spec sheets on functionality for bakers, maltsters, and feed operations for different varieties. Continue to educate our target audience through workshops and conferences- either in-person or virtual (Variety Showcase, Winter Vegetable Sagra, Cascadia Grains Conference, MOSES, Organic Seed Growers Conference, Organicology, Barley Day, Student Organic Seed Symposium, Organic World Congress). Gather and provide information on research and opportunities for growers, processors, bakers, and brewers to gain access to naked barley. Further outreach to feed suppliers and end users will be conducted to inform stakeholders about the project, assist in the development of the market, capture information on market potential and educate end users on the attributes of naked barley in feed rations. Conduct expanded outreach to professionals in the craft beverage and culinary sectors. Increase education and outreach through social media channels, Facebook, Instagram, Flickr and the GrowNYC Grains newsletter. Host in-person or virtual field days and other outreach events to increase community involvement and awareness. If possible, the annual project/stakeholder review meeting will be held in the Northeast in 2021. Find effective and safe ways to host field days, seminars and presentations to reach organic farming communities Research Use data to select lines in regional trials that exhibit target levels of food and malting traits. Use local data regarding environment specific factors affecting yield such as disease resistance, lodging, heading date, weed competitive ability to identify drives of local and broad adaptation. Initiate new crosses and continue to select and advance cross progeny for variety development. Conduct food and malt quality analysis on the grain harvested in 2020. Use the data from the diversity panel lines to investigate genes of interest in organic production. Grow the SRT that was not planted

in the spring of 2020 in Madison. Use the data from two seasons of diversity panel lines to investigate genes of interest in organic production through a GWAS analysis. This will allow us to better understand the genetic basis of agronomic traits of naked barley. Use increased seed from the 2020 regional experiments to do more in depth testing and analysis including baking and quality trials.

2017/09 TO 2021/08 Target Audience: Public outreach efforts for naked organic barley included speaking at virtual and in-person organic agriculture and grain-related conferences, workshops, and events. Such events have allowed us to engage a diverse audience about the potential use of naked organic barley. Additionally, digital material produced after in-person gatherings became unsafe has allowed us to reach an even broader audience. Producers/growers End-users Processors Grain retailers and wholesalers Millers Brewers Distillers Maltsters Organic poultry egg and meat producers Animal feed suppliers and feed mills Chefs Bakers Students K-12 students Undergrad and graduate students Urban agriculture students Academic and industry researchers Organic organizations General Public Instagram/Facebook viewers (733 followers, 114 posts on \@nakedbarley) Consumers and farmers market shoppers Business owners Changes/Problems: Covid-19 related Problem: Visits and experiments with K-12 schools could not be conducted as planned. Solution: Planned activities were canceled and were moved online for the 2020-2021 school year. Problem: We could not hold our 2021 annual meeting with stakeholders in NY. Solution: Researchers began meeting virtually every month with each other and stakeholders and are working on developing other virtual content to disseminate to stakeholders. Researchers held a 2-hour virtual meeting in May 2021 to gather the entire group for annual updates. Problem: Because of University restrictions placed on hiring summer labor, several of the programs were not able to employ hourly workers to help with research. Solution: Trials were maintained and analyzed to the best ability of the current employees. Problem: Social distancing and other restriction prevented a large gathering of people for field days at UW-Madison. Solution: A smaller, more informal event was held instead with specifically invited guests. Not Covid-19 related Problem: Weather and pests resulted in quality issues and missed planting opportunities. Solution: For harvested grain with quality issues (primarily pre-harvest sprouting as a result of rain prior to harvest), we have an opportunity to look at the different responses of the lines in the trial, which gives us useful breeding and selection information. Problem: As a result of equipment break-downs, poorly germinating grain, and crop failure, the grain for the malting and brewing trials was rendered unusable. Solution: The malting and brewing study is underway, but will be completed in the fall of 2021. Problem: Lines in the diversity panel were found to be genetically identical despite having separate names and coming from different sources. This presents challenges in performing GWAS and GS analysis. Solution: Genetically identical lines that displayed the same phenotype were relabeled to have the same name. Lines that were similar, but not completely identical were removed from the following analyses. Problem: Covered lines used as replicated checks in the diversity panel do not have variability for threshability. This is detrimental when calculating means of replicated lines, because there is not a good estimation of experimental error for threshability based on the replicated hulled lines. Solution: The hulled lines were removed from the analysis for threshability and the genetically identical lines previously mentioned were used as replicated checks instead. Problem: Shortage of grain for GrowNYC Grains to work with and market at the Grainstand. Solution: Activities pivoted to outreach to farmers. Progress was made with Small Valley Milling producing several varieties on a commercial scale in 2020. Outreach may yield future results in building general capacity for handling. Problem: Preharvest sprouting and smut damage at more than one location in more than one year made statistical analyses of the quality data challenging. Solution: As a result of withdrawal of the damaged samples from the data set either post-hoc (PHS) or prior to testing (smut) the design became unbalanced and did not allow a full factorial analysis for many traits. What opportunities for training and professional development has the project provided? Indirectly, attendance at conferences conveying the benefits of organic naked barley has allowed for development of professional networks and provided input regarding breeding goals for naked organic barley. Discussion of ideas and challenges at these conferences and events has provided training in how the goals and execution of the project should go forward. The graduate students have had many opportunities for professional development and training. They have learned many technical skills regarding experimental design, field work, data analysis, food science, weed management practices, public speaking, as well as a good sense of what working in academia is like. Attendance at meetings, field days and other activities have provided many opportunities to learn new ideas and points of view. Field related activities also provide the chance to learn many hands-on skills including field and plot management. Also, graduate students funded by this grant were able to learn technical and academic skills that they would not have otherwise been exposed to. Chris Massman, Karl Kunze, and Cristiana Vallejos, the breeding graduate students working on this project have also had the opportunity to develop data analysis and academic paper writing skills. They have had the opportunity to learn and work with different genomic methods in plant breeding including GWAS and genomic selection. They have also gained experience in writing and submission of completed research. Additionally, from interactions at field days or conferences, they have begun to develop valuable networks with researchers and farmers. Through presenting research proposals and results at various functions, they have improved their speaking ability. The food quality analyses being run at OSU have provided opportunities to train a

graduate student, Jordyn Bunting, and undergraduate in wet chemistry and other methods of analyzing flour and cooked grains. This has involved learning cereal quality analytical and end-product testing and assessment, experimental design, statistical analyses, oral and written communication skills. Brigid Meints (former Postdoc, now Assistant Professor) has had the opportunity to mentor all of the graduate students on the grant and serves on the thesis committee for the OSU graduate student. This project has provided her training in project management, organizing events, malting, disease inoculation, and new data analysis techniques. GrowNYC Grains staff have been trained on the breeding process and culinary attributes of barley through this project. The GrowNYC Teaching Garden staff planted the Oregon Naked Barley Blend in their teaching garden and at the NYU Urban Farm Lab and learned about growing small-scale grain grow-outs. How have the results been disseminated to communities of interest? Details of the project have been disseminated through email, personal correspondence and communication, conferences, social media, and websites. UW-Madison, Cornell, and UMN hosted in-person field days and OSU hosted virtual field days on Instagram Live. The UW-Madison person field day was attended by approximately twenty growers and other people in industry. Because of the small size, researchers were able to engage participants more directly in the question-and-answer sections of the event. Social media postings in Instagram and Facebook allow researchers to share project updates and photos with thousands of followers between @nakedbarley, @culinarybreedingnetwork, @eorganicofficial, and @gownycgrains. Brigid Meints from OSU presented at the Craft Malt Conference on malting and brewing naked barley. June Russell, Brigid Meints, and Karl Kunze participated in a panel discussion with project partners at the Philadelphia Grain and Malt Symposium on Naked Barley and Other Value-Added Grains. Brigid Meints, Pat Hayes, Jordyn Bunting, and Cristiana Vallejos of Oregon State University gave a presentation on the Multi-use Naked Barley project at the Culinary Variety Showcase. Available at <https://youtu.be/60V62G8yREo?t=5531>. Karl Kunze of Cornell University presented an eOrganic webinar entitled Progress on Organic Naked Barley Breeding: Exploration of Organic Breeding Traits. Available at <https://youtu.be/oW0FjpsbMo>. Brigid Meints and Andrew Ross participated in a barley workshop with Sarah Owens titled 'Bodacious Barley Workshop'. Researchers collaborated with a graphic designer to produce a barley zine, which includes information about the project and recipes developed by collaborators and stakeholders. A printed version has been distributed to 200 people and the digital version has reached hundreds more. Each of the breeding programs have uploaded phenotypic data from the regional trials and diversity panels to the T3 (Triticeae Toolbox: <https://triticeaetoolbox.org/barley/>) database. These data can be accessed by other breeding programs and researchers. Participants from this project teamed up with organizers of the Cascadia Grains Conference, and members of the Value-added Grains OREI project to host a week-long conference called 'Grains Week'. Five of the presentations (given by Brigid Meints, Cristiana Vallejos, Andrew Ross, Jordyn Bunting, Mark Sorrells, Julie Dawson, June Russell, Kevin Smith, and Pat Hayes) focused specifically on this project; the total view for the week were 5,403. This content is on YouTube and may garner further views in the future. Chris Massman presented regional trial results from the first cycle of the grant to CIAS faculty in October of 2021. The presentation was online and attended by approximately twelve people. A question-and-answer session followed the presentation. Chris Massman presented regional trial and diversity panel results from the first cycle of the grant to plant breeding and plant genetics students and faculty at UW Madison. The presentation was online and attended by approximately thirty people. A question-and-answer session followed the presentation. In collaboration with Portland-based Wellspend Market (retail, wholesale and online store), Barleyworld and Culinary Breeding Network promoted barley and barley products (whole grain and flakes) and a giveaway during Grains Week. Wellspend started offering locally grown, organic 'Streaker' barley flakes as a result of collaboration. Wellspend owner Jim Dixon and CBN director Lane Selman executed an Instagram live (1272 views) to discuss using barley in the kitchen. Wellspend created and promoted barley recipes thru social media and their website -recipeandcookie recipe. In collaboration with Portland-based pastamaker Emily Park, offered barley pasta kits for sale during Grains Week. In collaboration with PNW chain Burgerville (40 locations in WA and OR) organic hull-less barley has been included in their new "Seedlings" program. 'Purple Karma' barley is being distributed in kids meals at each location. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

## IMPACT

2017/09 TO 2018/08 What was accomplished under these goals? Progress has been made on each of the project goals. Goal 1: Growers, processors, and consumers were provided with information about naked organic barley at conferences, field days, through personal communication, and website postings. However, in this first year of the project we have not had much seed to work with. Now that trials have been harvested more information can be provided. Using the limited seed from trials conducted before the start of this grant, we mini-malted 'Buck' and provided malt to two breweries to experiment with. We conducted informal sensory exploration on breads, steamed grain, and biscuits with attendees at conferences and field days. Additionally, this

first year we worked to develop connections with new producers, brewers, and small businesses. Goal 2: For our regional variety testing program we grew advanced experimental breeding lines and released varieties in the fall and spring. For our fall trial, 18 advanced naked barley lines were tested at 6 sites in five states: Oregon, Washington, Minnesota, Wisconsin, and New York. For our spring trial, 18 naked barley entries were tested at 9 sites in six states: Oregon, Washington, Minnesota, Wisconsin, Michigan and New York. Additionally, each state collaborated with local farmers to grown one acre increase blocks; we had 3 winter sites with 2 varieties (Buck and #STRKR) and 5 spring sites with 3 varieties (CDC Clear, Purple Valley and MS10S4111-01). Notes on agronomic traits were taken in the field; analyses of agronomic data are in progress; and food and malt quality traits will be analyzed this coming fall. The fall-planted trials winter-killed in MN and WI, however we had success in growing moderate yielding organic winter naked barley in NY, OR, and WA. Despite a cold winter, our winterkill was moderately low for most varieties and because of the advantage that winter grains early emergence, most winter regional naked barleys were able to outcompete weeds. Analysis of food quality and malting of winter naked barley is underway. The spring trials survived at all locations and data are still being collected and analyzed. The increase blocks were successful and will be used for marketing, along with other extensive food quality tests. Goal 3: For the diversity panel, we assembled 254 spring and facultative naked barley lines from breeding programs and germplasm repositories around the world. These were trialed at 5 spring sites in single or double rows. An additional 130 winter lines were selected and grown out in the greenhouse. These will be added to the trial this fall to complete the panel. Tissue was collected from the panel and sent in for DNA extraction and genotyping. Agronomic traits were measured on this trial. Post-harvest and food quality trait will be conducted as seed supply permits. Integration of genotype and phenotype data will guide future selection decisions. Goal 4: Our outreach to K-12 students is being achieved by assisting teachers in all states with lesson plan development, seed increases, and selection. Through funding awarded from this project, the students have been able to grow and learn from the Oregon Naked Barley Blend. By growing barley in the garden and greenhouse, students are able to learn some of the concepts of barley production, management, harvest and post-harvest qualities of the naked barley grown. It is important to note that due to school schedules and the agronomic traits of barley, most students are not available when the spring barley is growing and thus it can be difficult to discuss the agronomic factors and challenges associated with growing naked barley. Thus, the education associated with the naked barley will have to be adapted to teach concepts that are easily tangible with the students, such as observation of the grain and the basic concepts of genetics and selection. Goal 5: Our agriculture economist is generating a literature review on the economic and environmental benefits of naked barley. In addition, he has begun developing questions that will appear on a 2019 grower survey regarding naked barley production and is in the process of developing an economic analysis of the feasibility of developing a small-farm scale integrated organic naked barley operation that includes grain production, malting, brewing, feeding, and culinary dimensions. GrowNYC has worked to assess the potential for naked barley in feed rations. Interviews were conducted with several representatives in the feed world. Two representatives from organic feed mills were also interviewed. Goal 6: Details of the project have been disseminated through email, personal correspondence and communication, field days at all universities, press releases, conferences, and websites. OSU hosted 'Barley Day 2018', which was a day-long field day focused on this project. It was held in conjunction with the annual project meeting and included collaborators from all states who gave presentations. 100 people attended, including brewers, chefs, bakers, growers, maltsters, processors, the general public, and college students. The other universities all held summer field days as well, where information about this project was shared with the general public. **\*\*PUBLICATIONS (not previously reported):\*\*** 2017/09 TO 2018/08 1. Type: Journal Articles Status: Published Year Published: 2017 Citation: Meints, B., Corey, A., Evans, C., Filichkin, T., Fisk, S., Helgerson, L., Ross, A.S. and Hayes, P.M., 2017. Registration of 'Buck' Naked Barley. Journal of Plant Registrations. 2. Type: Journal Articles Status: Submitted Year Published: 2018 Citation: Meints, B., and Hayes, P.M. Naked barley for food, feed, and malt. Plant Breeding Reviews

2018/09 TO 2019/08 What was accomplished under these goals? In the second year of the grant, project participants and other collaborators grew out over 400 naked barley lines in 21 certified organic trials, characterizing them for agronomic traits, food and malt quality traits, weed competitive ability, and resistance to abiotic and biotic stressors. With the results of these trials, we have begun new breeding work to select for traits necessary for organic production. Several hundred undergrads and K-12 students were exposed to the project through classroom visits and field trips where they learned about plant breeding, agronomy, and genetics in the context of naked barley. Through a farmer survey designed to learn more about the current status of organic barley in the US, we received over 80 responses which have improved our understanding of the economic feasibility of naked barley and have allowed us to focus our breeding targets. Hundreds of growers, processors, and consumers have been provided with trial results and information about naked organic barley at conferences, field days, through personal communication, and website postings. Goal 1: We conducted informal sensory exploration on breads, steamed grain, and biscuits with attendees at conferences and field days. Farmer collaborators were provided with enough grain to grow out one acre of naked barley as well as a small stipend.

Grain from one of the research increases in Oregon was used for the egg production feeding trial, which was recently concluded. The broiler project using more of that grain was recently started. Seed of four varieties was sent to Julie Dawson, who worked with a local baker to develop a sensory analysis protocol. Using a pita bread recipe, three professional bakers made pita breads from the four varieties and trained and public sensory analyses were conducted. Goal 2: Data analysis, including ANOVAs, correlations, and mean separations have been performed on agronomic data from the 2018 regional trials. Food quality analyses are in progress on the 2018 regional trials. Additionally, samples from the 2018 regional trials were analyzed for protein and beta-glucan using a near-infrared spectrometer. Micronutrient concentrations of milled samples were determined using an x-ray fluorescence spectrometer using a standard-less application. For the 2019 regional variety testing program we grew advanced experimental breeding lines and released varieties in the fall and spring. For our fall trial, 18 advanced naked barley lines were tested at 6 sites in four states. The trial was also sent to collaborators in Dublin, Ireland. For our spring trial, 18 naked barley entries were tested at 6 sites in four states. Additionally, each state collaborated with local farmers to grow one acre increase blocks; we had 4 winter sites and 5 spring sites with 2 varieties each. Notes on agronomic traits were taken in the field; analyses of agronomic data are in progress; and food and malt quality traits from these trials will be analyzed this coming fall. The fall-planted trials had differential winter survival in MN and WI, which allowed us to identify lines that have winterhardiness. The spring trials survived at all locations and data are still being collected and analyzed. The increase blocks were successful and will be used for marketing, along with other extensive food quality tests. Goal 3: For the diversity panel, we fall-planted 384 diverse naked barley lines in 3 states in single or double rows. The OR and NY locations survived the winter. The WI trial had differential winter survival and winterhardiness notes were taken. We spring-planted the 254 spring and facultative naked barley lines from the diversity panel at 4 spring sites. Agronomic traits were measured on this trial. On the mini-plots (grown in Corvallis), more extensive weed competitive ability notes were taken. Post-harvest and food quality trait will be conducted as seed supply permits. Additionally, the mostly full set of spring and facultative lines from the diversity panel were sent to Ireland, UC Davis, and Thailand. The panel grown in Ireland was used as leverage to get an Irish grant to fund a PhD student. The trial sent to Thailand was used to phenotype for rice blast (a disease that none of our collaborators in the US can test for) in the greenhouse and in the field. The entire panel was genotyped by the USDA lab in Fargo, ND. Integration of genotype and phenotype data will guide future selection decisions. Additionally, GWAS has been conducted on the phenotypes collected in the 2018 trials, including leaf rust, stripe rust, heading date, threshability, early plant vigor, and canopy cover. Significant peaks were identified for all traits. Using the data collected on the diversity panel, parents have been selected and crossing projects have begun in all states. Goal 4: Our outreach to K-12 students is being achieved by assisting teachers in all states with lesson plan development, seed increases, and selection. This year in Oregon we expanded the K-12 education scope from looking at natural and artificial selection to exploring how nitrogen affects individuals' growth in a barley population and how different plant populations are affected by nitrogen. Seventh grade students had the opportunity to taste and plant barley foods as well as analyze data from greenhouse grown plants and then work with researchers. In New York, the students observed listed traits and determined which traits would be the most useful for selective breeding. They collected data on seed number per spike, awns per spike, and made data charts and a graph and then made selections based on awn presence and seed counts per spike that were over 25. At UW-Madison, multiple field trips from a local middle school were hosted this year. Over 150 students had the opportunity to plant seed of their choosing and help in characterizing the plants that grew. The resulting data provides characterization of the ONBB after selection by middle school students. Goal 5: Our agriculture economist distributed a grower survey regarding organic barley production and is in the process of developing an economic analysis of the feasibility of developing a small-farm scale integrated organic naked barley operation that includes grain production, malting, brewing, feeding, and culinary dimensions. The survey was closed in April with 84 organic barley producer respondents. The data has been analyzed a report was published on eOrganic. Half of the producers surveyed have agreed to follow-up interview. Once all data have been collected, the results of the survey and interviews will be written up for journal publication. Goal 6: Details of the project have been disseminated through email, personal correspondence and communication, field days at all universities, press releases, conferences, and websites. OSU hosted a half-day field day focused on this project. Additionally, UW-Madison hosted an Organic Barley field day that was held in conjunction with the annual project meeting and included collaborators from all states who gave presentations. Seventy-five people attended, including growers, maltsters, processors, bakers, the general public, and college students. The other universities all held summer field days as well, where information about this project was shared with the general public. GrowNYC co-hosted the 2019 Variety Showcase event in partnership with the Culinary Breeding Network. The event includes a series of tables featuring plant breeders with examples of their breeding work. That same day, the GrowNYC Grainstand attended GrowNYC's flagship Union Square Greenmarket and launched the retail sale of Buck, #STRKR and Purple Valley barley. In collaboration with the researchers from OSU and Cornell, GrowNYC hosted their first public and professional outreach event on naked barley with a target audience of brewers and distillers and NYC bakers who have shown an interest in regional grains. Approximately 25 people attended. \*\*PUBLICATIONS (not

previously reported):\*\* 2018/09 TO 2019/08 Type: Book Chapters Status: Published Year Published: 2019  
Citation: Meints, B., & Hayes, P. M. Breeding Naked Barley for Food, Feed, and Malt. *Plant Breeding Reviews*, 95-119

2019/09 TO 2020/08 What was accomplished under these goals? In the third year of the grant, participants grew out the final year of trials for this project. This involved growing over 400 naked barley lines in certified organic trials, characterizing them for agronomic traits, food and malt quality traits, weed competitive ability, and resistance to abiotic and biotic stressors. With the results of these trials, we have begun new breeding work to select for traits necessary for organic production. Journal and extension publications are in preparation to disseminate the results of these experiments to researchers and growers. Survey and interview results looking at the economic feasibility of growing organic barley have been published and will continue to be made available to growers. Hundreds of growers, processors, and consumers have been provided with trial results and information about naked organic barley at conferences, virtual field days, through personal communication, website postings, and social media. Goal 1: The value of naked barley as a new potential crop was described to stakeholders through a variety of mechanisms. Using existing and potential new varieties, we conducted informal sensory exploration with porridge breads, steamed grain, cookies, and roasted barley tea at conferences and outreach events. Grain from one of the research increases in OR was used to conduct the poultry broiler project. In OR and MN, grain increases of MS10S4111-01, an advanced breeding line, were conducted for large-scale end-use testing and distribution to interested end-users. At UW-Madison, sensory analysis on food grade naked barley was performed with professional bakers. Bakers worked with flour from different naked lines to replicate a sugar cookie recipe and a pita recipe. Baked goods were then sampled by customers and other researchers in a blind taste test. Researchers at UW-Madison convened a discussion of key stakeholders, including farmers, bakers, millers and seed company representatives to share these results. In a separate meeting, baking and field trial results were shared with the Artisan Grain Collaborative leadership and members. Goal 2: Data analysis, including ANOVAs, correlations, and mean separations have been performed on agronomic data from the 2018-19 regional trials. A combined analysis of regional trial data from the 2018 and 2019 seasons was performed to assess lines in the panel as well as determine the observed variance attributable to genetic, environmental and genotype by environmental effects. A variety of methods was used including ANOVA, Spearman correlations between genotypic rankings in each environment, GGE models, and random effects models. Extensive food quality and functionality analyses are in progress on the 2019 regional trials. For the 2019-20 regional variety testing program we grew advanced experimental breeding lines and released varieties in the fall and spring. For our fall trial, 18 advanced naked barley lines were tested at five sites in four states. For our spring trial, 18 naked barley entries were tested at 4 sites in three states. Notes on agronomic traits were taken in the field; analyses of agronomic data are in progress; and food and malt quality traits from these trials will be analyzed this coming fall. The fall-planted trials had high winter survival for the first time during this project in WI and MN, which allowed researchers there to analyze trials for the full panel of agronomic traits. The fall regional trial was included in an inoculated Fusarium Head Blight (FHB) nursery in NY to test for disease reaction and deoxynivalenol (DON, a mycotoxin) levels. The spring trials survived at all locations and data are still being collected and analyzed. To collect more quantifiable data at the Cornell site, we have utilized weekly aerial imaging on our spring naked barley regional trials for both 2019 and 2020 field seasons. Imaging has been conducted weekly from the end of May until the beginning of July for both years. Goal 3: Analysis of 2018-19 diversity panels was conducted. Preliminary analysis of genotyped lines in the diversity panel has been performed in preparation for GWAS and GS studies. This includes calculation of LD decay, PCA for genetic relationship between lines, and dendrograms for genetic relationship. Preliminary GWAS analysis has revealed significant hits for winter survival, maturity date, heading date, plant height, early plant vigor, stripe rust, and leaf rust. For the 2019-20 season, we fall-planted the full diversity panel (384 diverse naked barley lines) in two states. The OR location survived the winter. The NY trial had differential winter survival and winterhardiness notes were taken. A subset of 14 lines that showed good winterhardiness in the WI 2018-19 trial was fall-planted in WI and MN in 2019. We spring-planted the 254 spring and facultative naked barley lines from the diversity panel at 3 spring sites. Agronomic and disease resistance were measured on this trial. The spring panel was additionally planted in an inoculated FHB nursery in MN. On the mini-plots (grown in OR), more extensive weed competitive ability notes were taken. Post-harvest and food quality trait will be conducted as seed supply permits. Goal 4: In-person classroom visits had to be cancelled as a result of Covid-19. However, researchers are continuing to work with teachers to find ways to provide distance learning and educational resources safely. K-12 teachers and project researchers are working together to transition lesson plans from in-person to virtual activities. Additionally, new lesson plans that meet curriculum standards for multiple grade levels are being created that will have options for in-person or virtual learning. The Oregon Naked Barley Blend has been distributed to teachers and continues to be distributed to interested home gardeners for planting and selection. The blend was distributed to all survey participants as well as conference attendees and interested parties who visit [barleyworld.org/onbb](http://barleyworld.org/onbb). Goal 5: Our agriculture economist distributed a grower survey in 2019 regarding organic barley production. Of the 84 respondents, 19 were selected for follow-up

interviews to represent different region, scale, and end-uses for the barley they produced. The interviews were recorded and summarized. Data collected from organic farmers identified the phenotypic traits desired by organic barley producers. Organic farmers also provided information on production challenges, such as diseases, that the breeders can use to select and improve varieties suitable for organic and sustainable farming conditions. Cost of production data was also obtained to prepare model budgets that can be used as planning tools by organic barley producers. The results were written up in a journal article that was published in *Organic Agriculture* and an extension article that is currently under review for *eOrganic*. Both publications are open access, so they are available to the target audience. Survey respondents were informed of the publications. Goal 6: Details of the project have been disseminated through email, personal correspondence and communication, virtual field days, conferences, and websites. Researchers participated in the 2020 Variety Showcase and 2019 Winter Vegetable Sagra hosted by the Culinary Breeding Network. These event includes a series of tables featuring plant breeders and farmers with examples of their breeding work. A combined 1700 people attended these events and met with researchers to learn about the project and try foods made with naked barley. The postdoc and graduate students on the project gave academic seminars and extension presentations at several conferences over the winter, reaching hundreds of academics, growers, bakers, millers, chefs, and processors. The *eOrganic* website is updated to reflect progress of the project and contains bulletins, publications, webinars, and social media accounts. \*\*PUBLICATIONS (not previously reported):\*\* 2019/09 TO 2020/08 1. Type: Journal Articles Status: Published Year Published: 2020 Citation: Baker, B.P., Meints, B.M. and Hayes, P.M., 2020. Organic barley producers' desired qualities for crop improvement. *Organic Agriculture*, 2020, pp.1-8. 2. Type: Journal Articles Status: Published Year Published: 2020 Citation: Hernandez, J., Meints, B. and Hayes, P., 2020. Introgression Breeding in Barley: Perspectives and Case Studies. *Frontiers in Plant Science*, 11, p.761. 3. Type: Journal Articles Status: Under Review Year Published: 2020 Citation: Baker, B.P., Meints, B.M. and Hayes, P.M., 2020. Organic and Naked Barley: Practices, Production Costs, and Benefits. *eOrganic*.

2017/09 TO 2021/08 What was accomplished under these goals? In the final year of the grant, participants worked on conducting end-use quality tests and analyzing data from over 400 naked barley lines grown in certified organic trials during the first three years of the project, characterizing them for agronomic traits, food and malt quality traits, weed competitive ability, and resistance to abiotic and biotic stressors. These analyses include characterizing the genotype by environment interactions for agronomics and food quality of naked barley germplasm as well as investigating the genetic basis of threshability, weed competitive ability, and resistance to a range of diseases. Understanding these characteristics allows breeders to make optimal decisions for selecting the best barley variety in their region. With the results of these trials, we have begun new breeding work to select for traits necessary for organic production. Journal and extension publications are in preparation to disseminate the results of these experiments to researchers and growers. Survey and interview results looking at the economic feasibility of growing organic barley have been published and will continue to be made available to growers. Hundreds of growers, processors, and consumers have been provided with trial results and information about naked organic barley at conferences, virtual field days, through personal communication, website postings, and social media. Goal 1: The value of naked barley as a new potential crop was described to stakeholders through a variety of mechanisms. In MN, a six-acre grain increase of MS10S4111-01, an advanced breeding line, were conducted for large-scale end-use testing and distribution to interested end-users. At UW-Madison, sensory analysis on food grade naked barley was performed with professional bakers. Bakers worked with flour from different naked lines to replicate a sugar cookie recipe and a pita recipe. Baked goods were then sampled by customers and other researchers in a blind taste test. Researchers at UW-Madison convened a discussion of key stakeholders, including farmers, bakers, millers and seed company representatives to share these results. Goal 2: Data analyses, including ANOVAs, correlations, and mean separations have been performed on agronomic data from the regional trials. A combined analysis of regional trial data from all three seasons was performed to assess lines in the panel as well as determine the observed variance attributable to genetic, environmental and genotype by environmental effects. A variety of methods was used including ANOVA, Spearman correlations between genotypic rankings in each environment, GGE models, and random effects models. This agronomic yield trial data is being analyzed to identify regions where genotypes perform similarly, also known as mega-environments. This information will allow breeders to tailor selections to the regional level and allow the best possible genotypes to be released to growers. A Finlay-Wilkinson analysis has also been used to identify genotypes that show high or low sensitivity to their environment. Results from these analyses are being prepared in a manuscript for publication. Key food quality traits have been characterized on the regional trials. Samples of spring, winter, and facultative barley from Corvallis OR, Freeville NY, Madison WI, and Arlington WI over three harvest years (2018, 2019, and 2020) were tested for moisture, kernel hardness, beta-glucan levels, and multiple components of flour/starch pasting properties. In addition, 450 of the above samples were subjected to extended testing that encompassed protein, flour water absorption, flour/water batter flow properties, cooked grain texture (hot and cold), and cooked grain yields. Color was quantified on grain, whole-grain flour, and cooked wholegrains from these samples using a tristimulus color meter. Investigations targeted the efficiency of breeding selection via

integration of phenotypic and genotypic data and statistical analyses. Statistical analysis may lead to the identification of a small number of key food traits that can categorize naked barley, aid in breeding selections, and aid buyers and processors in identifying the correct type of organic naked barley for their specific end-uses\.

Goal 3: Analysis of data from all three years of diversity panel grow-outs was conducted. Preliminary analyses of genotyped lines in the diversity panel have been performed in preparation for GWAS and GS studies. This includes calculation of LD decay, PCA for genetic relationship between lines, and dendrograms for genetic relationship. Preliminary GWAS analysis has revealed significant hits for winter survival, maturity date, heading date, plant height, early plant vigor, stripe rust, and leaf rust. Threshability, or ease of hull loss, was identified as a key trait for naked grains in the first cycle of the grant. Grain failing to shed its hull loses the advantages of naked grains over covered grain. Despite its importance, there is not a large amount of published information on threshability. Using information from the diversity panel, research was done in the genetic basis and plausibility of genomic selection for threshability. The data set includes five environments where threshability was scored for 350 distinct barley genotypes. GWAS was performed to identify QTL with a significant association to threshability. Results from these analyses are being prepared in a manuscript for publishing.

Goal 4: In-person classroom visits had to be cancelled as a result of Covid-19. However, researchers are continuing to work with teachers to find ways to provide distance learning and educational resources safely. K-12 teachers and project researchers are working together to transition lesson plans from in-person to virtual activities. Additionally, new lesson plans (<https://oregonaitc.org/lessonplan/the-f2-generation-of-buck-and-lightning/> and <https://oregonaitc.org/lessonplan/the-barley-family-observable-traits-of-barley/>) that meet curriculum standards for multiple grade levels were created that will have options for in-person or virtual learning. The Oregon Naked Barley Blend has been distributed to teachers and continues to be distributed to interested home gardeners for planting and selection.

Goal 5: Our agriculture economist distributed a grower survey in 2019 regarding organic barley production. The results were written up in a journal article that was published in *Organic Agriculture* and an extension article that is available at eOrganic. Both publications are open access, so they are available to the target audience. Survey respondents were informed of the publications. Additionally, he prepared a short presentation for the 2021 Organic World Congress conference.

Goal 6: Details of the project have been disseminated through email, personal correspondence and communication, virtual and in-person field days, virtual conferences, and websites. The eOrganic website is updated to reflect progress of the project and contains bulletins, publications, webinars, and social media accounts. Due to Covid-19, the 2021 Variety Showcase was moved online to YouTube. Four members of the group presented during a session that received 839 unique views. Additionally, participants from this project teamed up with organizers of the Cascadia Grains Conference, and members of the Value-added Grains OREI project to host a week-long conference called 'Grains Week'. Five of the presentations focused specifically on this project; the total view for the week were 5,403. This content is on YouTube and may garner further views in the future. Participants presented at the Virtual Craft Malt Conference, Virtual Philly Malt and Grain Symposium, Virtual 2020 National Scab Forum, and at various workshops and other events. Participants at OSU hosted two Instagram live field tours for a total of 294 views. Participants at UMN and UW-Madison were able to hold in-person field days.

**\*\*PUBLICATIONS (not previously reported):\*\*** 2017/09 TO 2021/08 Type: Journal Articles Status: Accepted Year Published: 2021 Citation: Meints, B., Vallejos, C. and Hayes, P.M. 2021. Multi-use Naked Barley: A New Frontier. *Journal of Cereal Science*. \*\* \*\*

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# Working Toward Best Management Practices for Organic Beekeeping: a Side - by - Side Comparison of Management System

<b>Accession No.</b>	1013015
<b>Project No.</b>	PENW-2017-02476
<b>Agency</b>	NIFA PENW\
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26814
<b>Proposal No.</b>	2017-02476
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2020
<b>Grant Amount</b>	\$995,540
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Lopez-Uribe, M. M.; Traver, BR, EL.
<b>Performing Institution</b>	PENNSYLVANIA STATE UNIVERSITY, 408 Old Main, UNIVERSITY PARK, PENNSYLVANIA 16802-1505

## NON-TECHNICAL SUMMARY

The beekeeping industry is facing serious challenges to maintain the high numbers of honey bee colonies required to meet the demands for crop pollination. Currently, most managed honey bee colonies cannot survive the winter without disease treatment, and even with an intensive management regime, beekeepers nationwide are averaging 40% yearly losses. Various practices are used to manage colonies, including conventional, organic, and chemical-free systems. There is a critical need for improved organic system that can better control parasitic mite pressure given that mite control chemicals can be detrimental to overall bee health. Generating research-based and economic data that support organic beekeeping management practices is therefore key to improving organic agriculture by creating a profitable economic opportunity for beekeepers and organic growers. In this project, we will rigorously test the effect of organic, chemical-free and conventional honey bee management systems on honey bee health by quantifying (1) colony performance, (2) immunocompetence, and (3) parasite and pathogen levels. In addition, we will (1) quantify pesticide residues in beeswax from colonies in the three management systems, (2) develop an economic assessment of the cost-benefits of the different management systems, and (3) establish a long-lasting extension program to assist stakeholders with incorporation of alternative beekeeping management systems.

## OBJECTIVES

Our end goal is to improve honey bee colony health through best management practices for organic beekeeping. Specifically, our objectives are:

- \* Objective 1: Conduct a side-by-side comparison of the impact of three management systems (organic, chemical-free, and conventional) on honey bee colony health. Specifically, we will investigate (1a) colony performance, (1b) immunocompetence, and (1c) parasite and pathogen levels.
- \* Objective 2: Quantify cumulative pesticide residues in wax used by bees maintained with different management systems.
- \* Objective 3: Conduct a cost-benefit analysis of honey bee management systems to quantify the profitability of each of these systems to beekeepers.
- \* Objective 4: Work with the advisory panel on extension activities that will lead to behavioral changes in conventional and organic beekeepers interested in alternative management practices.

## APPROACH

We will assess how organic and chemical-free management systems differ and we will compare them to a conventional system in (1) impacts on honey bee health, (2) amounts of chemical residues in wax, and (3) economic costs to beekeepers. To holistically assess the status of honey bee health, we will quantify key aspects of each colony: (1a) colony performance, (1b) immunocompetence, and (1c) parasite and pathogen levels.

**Objective 1:** To evaluate the impact of organic, chemical-free and conventional management systems on honey bee colony performance, immunocompetence, and parasite and pathogen levels, we will set up 9 apiaries, each containing 30 Langstroth hives (270 total colonies). In each apiary, there will be three sets of 10 colonies kept 300 meters apart. Colonies will be assessed for varroa monthly, and samples will be collected for *Nosema* and immunocompetence analyses on a bi-monthly basis.

**Objective 2:** To quantify cumulative pesticide residues in wax used by bees maintained with different management systems, wax samples from each colony will be collected in the Fall of years 1 and 2 of this study. Wax will be purified and analyzed for chemicals that include cymiazole, coumaphos, chlorfenvinphos, fluvalinate, amitraz, and chlorothalonil.

**Objective 3:** To conduct the cost-benefit analysis of honey bee management systems, we will collect detailed notes throughout the experiment. We will record the amount of time spent working each colony, the cost of honey bee feed and the cost and time required for chemical inputs. We will then compile a maintenance cost per colony for each management system for the economic analysis.

**Progress** 09/01/17 to 08/31/22 **Outputs** Target Audience: Our main target audience throughout this project was small or mid-scale stationary beekeepers. One of the great achievements of this project has been creating bridges of communication between beekeepers who manage honey bees using conventional practices and beekeepers who choose to manage bees without using hard chemicals. The latter group has historically been marginalized from mainstream beekeeping meetings because of their ideology for bee management. We have successfully brought together these groups of beekeepers to have open discussions about beekeeping practices. Through over 25 talks and workshops at beekeeping clubs, and regional, national, and international conferences, we have reached an audience of approximately 5,000 beekeepers and farmers about the topic of our project and the promising results of establishing a protocol to keep bees exclusively under organic treatments.

Extension talks and audiences 2017 to 2022: Underwood RM, Butzler T, Berner S. Organic Honey Bee Colony Management. All-day hands-on workshop to follow up on the webinar series. (August 27th, 2022; 15 participants). Underwood RM, Butzler T, Berner S. Organic Honey Bee Colony Management. All-day hands-on workshop to follow up on the webinar series. (June 9th, 2022; 13 participants). Underwood RM, Butzler T, Berner S. Organic Honey Bee Colony Management. All-day hands-on workshop to follow up on the webinar series. (June 2nd, 2022; 10 participants). Underwood RM, Butzler T, Berner S. Organic Honey Bee Colony Management. All-day hands-on workshop to follow up on the webinar series. (May 26th, 2022; 13 participants). Underwood RM, Butzler T, Berner S. Organic Honey Bee Colony Management. All-day hands-on workshop to follow up on the webinar series. (May 11th, 2022; 15 participants). Lopez-Urbe MM. Beekeeping philosophy and the benefits of organic beekeeping management practices. Young Harris Institute, Young Harris, GA (May 20th, 2022; 40 participants). Underwood RM, Lopez-Urbe MM, Butzler T. Monitoring and Integrated Pest Management (IPM) - a beekeeper's year. Organic Honey Bee Colony Management. Penn State Extension Webinar Series. (February 22nd, 2022; 142 participants) Underwood RM, Lopez-Urbe MM, Butzler T. Incorporating genetic stocks into beekeeping management. Organic Honey Bee Colony Management. Penn State Extension Webinar Series. (February 15th, 2022; 142 participants) Underwood RM, Lopez-Urbe MM, Butzler T. Dealing with Varroa Mites Using Approved Organic Chemicals. Organic Honey Bee Colony Management. Penn State Extension Webinar Series. (February 8th, 2022; 142 participants) Underwood RM, Lopez-Urbe MM, Butzler T. Dealing with Varroa Mites using Cultural & Mechanical Approaches. Organic Honey Bee Colony Management. Penn State Extension Webinar Series. (February 1st, 2022; 142 participants) Underwood RM, Lopez-Urbe MM, Butzler T. Beekeeping Philosophy in the Context of Teaching a Beginner's Class. Organic Honey Bee Colony Management. Penn State Extension Webinar Series. (January 18th, 2022; 142 participants) Underwood RM, Lopez-Urbe MM. An update on the COMB project: three years of data. Montgomery County Beekeepers Association, PA. Virtual. (September 23rd, 2021; 45 participants) Underwood RM, Lopez-Urbe MM. The impacts of management on honey bee health: a comparison of three management systems. Honey Bee Veterinary Consortium Conference, NC State University. Virtual. (September 2021; 60 participants) Underwood RM, Lawrence B, Kietzman P, Traver BE, Lopez-Urbe MM. The impacts of management on honey bee health: a comparison of three management systems. IPM4Bees, Iowa State University, IA. Monthly seminar. Virtual. (September 2nd, 2021; 6 participants) Underwood RM, Lawrence B, Kietzman P, Traver BE, Lopez-Urbe MM. COMB project update, Beekeepers of the Armstrong, Butler, Clarion, and Indiana (ABCI) counties conference. Kittanning, PA. (August 21st, 2021; 62 participants). Underwood, RM, Lopez-Urbe, MM. The Beekeeping Continuum and a scientific comparison of three management systems. Catskill Mountain Beekeepers' Club, NY. Virtual. (July 13th, 2021; 42 participants)

Underwood RM, Lopez-Uribe MM. An analysis of three honey bee colony management systems. Three Rivers Beekeeping Meeting, MO. Virtual. (March 15th, 2021; 125 participants) Underwood RM, Kelsey, T, Lopez-Uribe, MM. Beekeeping Economics. Great Plains Master Beekeepers Virtual Fun Day. (February 13th, 2021; 126 participants) Underwood RM. An organic management system for honey bees. Penn State Webinar Series, University Park, PA. (November 11th, 2020; 1,376 participants) Underwood RM, MM Lopez-Uribe with panelists M Gingrich, L Stahl, V Aloyo. Beekeeping Philosophy. Penn State Webinar Series, University Park, PA. Virtual. (November 4th, 2020; 1,259 participants) Underwood, R., B. Traver, P. Kietzman, K. Evans, M. Lopez-Uribe. Project COMB: Conventional and Organic Management of Bees. Meeting of the Wayne County Beekeepers Association, Honesdale, PA. (September 10th, 2018; 40 participants) Underwood R, B Traver, M Lopez-Uribe. A side-by-side comparison of honey bee health in colonies managed using conventional, organic, and chemical-free systems. Apimondia: International Apicultural Conference. Montreal, Quebec, Canada. (September 8th, 2019; 940 participants) Lopez-Uribe MM. COMB Project: Conventional and Organic Management of Bees. Chester County Beekeeping Association, West Chester, PA (March 9th, 2019; 40 attendees) Lopez-Uribe MM, Underwood RM. Honey bee health and organic beekeeping management practices. Pennsylvania Association for Sustainable Agriculture (PASA). Lancaster, PA USA (February 2019; 50 attendees) Underwood R, Evans K, Lopez-Uribe MM. COMB Project: Technical training. State College, PA USA (March 16th 2018; 12 attendees) Underwood, R. Treatment Free Research Project with Penn State. Treatment Free Beekeeping Conference, Oracle, AZ (March 2nd, 2018; 20 participants). Underwood R, Evans K, Lopez-Uribe MM. COMB Project: First stakeholder meeting. State College, PA USA (November 17th 2017; 30 attendees) Changes/Problems: The COVID-19 pandemic affected our ability to meet deadlines following the initial timeline. The graduate student who was working on this project was on leave for almost one year. Later, we hired a part-time technician to help with the lab work and data analyses, and that person left the position because she found a permanent job outside of academia. As a result, peer-reviewed publications are still in process. One was already submitted, and 2 are in preparation with an expected time of submission of February 2023. What opportunities for training and professional development has the project provided? We had the opportunity to train dozens of less experienced beekeepers throughout this project. Most of them were hired as wage employees to work with us on this project, others were members of the advisory panel who collaborated with us on the data collection and protocol development. These training opportunities have engaged communities that cannot access online information about beekeeping, such as Amish farmers. We have also given talks during the Spanish session of the Mid-Atlantic Vegetable Convention in Hershey PA about the economic opportunity that beekeeping could offer to farmers. In addition, one Master's student completed her thesis work researching this project (one paper was submitted, and there is one in preparation). This student is currently working as a high school science teacher and she is hoping to develop a beekeeping curriculum to teach STEM to these students through honey bee biology. One part-time postdoc was trained on qPCR to help generate the laboratory data for the main paper coming out of this project. Two postdocs have collaborated with us on the data analysis aspect of the project. ? How have the results been disseminated to communities of interest? The results of our project have been disseminated to the scientific community (through conference talks and posters, and peer-reviewed articles), and to the beekeeping community (through webinars, talks, workshops, and factsheets). What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported \*\*Impacts\*\* What was accomplished under these goals? Objective 1: Conduct a side-by-side comparison of the impact of three management systems (organic, chemical-free, and conventional) on honey bee colony health. We investigated (1a) colony performance, (1b) immune gene expression, and (1c) parasite and pathogen levels to quantify the effect of different beekeeping management practices on honey bee colony health. We completed three years of data collection for this objective. Our results indicate that the colonies in the organic and conventional management systems have similar levels of survival, honey production, immune gene expression, and levels of pathogens. This is one of the most important findings of this study as it demonstrates that beekeepers do not need to use synthetic chemicals to keep healthy and productive honey bees. In an additional project that investigated the impact of miticide applications on the bee bread microbiome, we detected an increase in the relative abundance of beneficial bacteria such as *Lactobacillus kunkeei* after organic miticide treatments. Because the application of formic acid to the colony likely lowers the pH of the bee bread, our results suggest that organic miticide applications may create an environment that favors the growth of beneficial bacteria in the bee bread. (Outputs: one paper was published, one is submitted, and one is in preparation) Objective 2: Quantify cumulative pesticide residues in wax used by bees maintained with different management systems. Wax comb collected from colonies managed under the three management systems (organic, conventional, chemical-free) showed low traces of pesticide residues. Of the 93 agricultural and apicultural chemicals included in the pesticide analysis (<https://blogs.cornell.edu/ccecf/the-facility/>), only 23 were detected in any of our samples. The three most common compounds were metolachlor (herbicide), piperonyl butoxide (synergistic compound), and fenpyroximate (miticide used for leafhoppers, mealybugs, other mites), which are all considered "no bee precaution" by the EPA. Results from wax comb pesticide residues collected from colonies foraging on organic land are 100 times lower than the values previously reported for colonies foraging on conventional

agricultural land. We are currently in conversations with members of EPA to begin conversations about the development of guidelines for what would be allowable levels of certain pesticides in honey in order to be able to market these products as organic. (Outputs: one short communication paper is in preparation) Objective 3: Conduct a cost-benefit analysis of honey bee management systems to quantify the profitability of each of these systems to beekeepers. We found that the operations following an organic management system are the most profitable. During the last year of the experiment when colonies were established and most productive, colonies managed under the organic management system produced on average 34% and 45% more honey than colonies in the chemical-free and conventional systems, respectively. These differences in honey production resulted in \$238 of income per colony for colonies in the organic system compared to \$165 for colonies in the conventional system. Low overwintering survival in the control (CF) group drastically decreased total honey production and profits over time. (Outputs: one paper is in preparation) Objective 4: Work with the advisory panel on extension activities that will lead to behavioral changes in conventional and organic beekeepers interested in alternative management practices. Throughout the project, we had close communications with the stakeholder group comprised of 30 experienced beekeepers who use different management practices (chemical-free, organic, conventional). These stakeholders were involved with the development of the management protocols (representing the conventional, organic, and chemical-free systems), and were later on key for the dissemination of our results. We presented updates about the results of the project yearly throughout the duration of the project. Thus, the goal of having constant stakeholder input for our project was successfully accomplished. Our results support that organic beekeeping offers several benefits to beekeepers as they can avoid the use of hard chemicals while keeping highly productive honey operations. We published extension articles, gave over 30 talks to national and international beekeeping groups, and offered a webinar series followed by a hands-on workshop. With all of these training opportunities, we have reached over 15,000 beekeepers. **Publications** - Type: Journal Articles Status: Under Review Year Published: 2023 Citation: Underwood RM, Lawrence B, Turley NE, Cambron-Kopco L, Kietzman P, Traver BE, López-Urbe MM. (In review) A longitudinal experiment demonstrates that organic beekeeping management systems support healthy and productive honey bee colonies. Scientific Reports. - Type: Journal Articles Status: Other Year Published: 2023 Citation: Lawrence B, Custer GF, Underwood RM, Dunn RR, Dini-Andreote F, López-Urbe MM. Honey bee bread is characterized by a core microbiome despite large effects of geography and miticide treatments (In preparation for ISME Communications) **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience: Our main targeted audience is beekeepers. One of the great achievements of this project has been the ability to create bridges of communication between beekeepers who manage honey bees using conventional practices and beekeepers who choose to manage bees without the use of chemicals. The latter group has historically been marginalized from mainstream beekeeping meetings because of their ideology for bee management. We have successfully brought together these groups of beekeepers to have open discussions about beekeeping practices. Through over 50 talks and workshops at beekeeping clubs, regional, national and international conferences, we have reached an audience of approximately 15,000 beekeepers and farmers about the topic of our project and the promising results of establishing a protocol to keep bees exclusively under organic treatments. Extension activities for the year 2021 included the following talks: Underwood RM, Lopez-Urbe M. Sep. 23, 2021. An update on the COMB project: three years of data. Montgomery County Beekeepers Association, PA. Virtual. 45 participants Underwood RM, Lopez-Urbe M. Sep. 18, 2021. The impacts of management on honey bee health: a comparison of three management systems. Honey Bee Veterinary Consortium Conference, NC State University. Virtual. 60 participants Underwood RM, Lawrence B, Kietzman P, Traver BE, López-Urbe MM. Sep. 2, 2021. The impacts of management on honey bee health: a comparison of three management systems. IPM4Bees, Iowa State University, IA. Monthly seminar. Virtual. 6 participants Underwood RM, Lawrence B, Kietzman P, Traver BE, López-Urbe MM. Aug. 21, 2021. COMB project update, Beekeepers of the Armstrong, Butler, Clarion, and Indiana (ABCI) counties conference. Kittanning, PA. 62 participants Underwood, RM, Lopez-Urbe, M. July 13, 2021. The Beekeeping Continuum and a scientific comparison of three management systems. Catskill Mountain Beekeepers' Club, NY. Virtual. 27 participants Underwood RM, Lopez-Urbe MM. Mar. 15, 2021. An analysis of three honey bee colony management systems. Three Rivers Beekeeping Meeting, MO. Virtual. 36 participants Underwood RM, Kelsey, T, Lopez-Urbe, MM. Feb. 13, 2021. Beekeeping Economics. Great Plains Master Beekeepers Virtual Fun Day. 126 participants López-Urbe MM, Underwood RM, with panelists Noorlander C, Gagne J, Whealan K. Feb. 6, 2021. Beekeeping philosophy and the range of options in management practices. New Mexico Virtual Winter Conference. 72 participants Underwood et al. Jan. 21, 2021. Fourth Annual COMB Stakeholder Meeting Virtual. 30 participants. **Changes/Problems:** The COVID-19 pandemic had some impact on our ability to collect data from the established colonies for this project in 2021. Specifically, we had planned to visit all colonies every 2 weeks (as was done in previous years) and we were only able to visit the colonies every 4 weeks. However, we completed the data collection for 3 years. The major challenge at the moment is to finalize the data analysis for the publication of the data. However, we have almost completed that part and will be submitting two of the major papers for publication before the next reporting cycle. What opportunities for training and professional development has the project provided? We have had the opportunity to

train less experienced beekeepers who have been hired as wage employees to work with us on this project. These training opportunities have engaged communities that cannot access online information about beekeeping such as Amish farmers. During this project, they have learned with us how to do advanced beekeeping, and how these different management types differ. In addition, one Master's student has been involved with this project. She is involved with the field data and sample collection and she is leading the laboratory analysis for the immune gene expression and viral work as well as the bee bread microbiome study. How have the results been disseminated to communities of interest? We held three stakeholder meetings throughout the duration of the project, and we continue to give talks to beekeeping clubs, and national/international conferences. Regionally, beekeepers are aware of our project because of talks at the State Beekeeping Meeting and local clubs. Nationally, we have presented talks at the American Bee Conference attended by over 100 scientists and beekeepers from the US and Canada. Internationally, we have shared our research at Apimondia with thousands of participating scientists and beekeepers from all around the world. What do you plan to do during the next reporting period to accomplish the goals? Remaining activities include: (1) completing the laboratory analyses of the samples to quantify viruses and immune gene expression, (2) finalizing statistical analyses of the management data, (3) finalizing data analysis of the economic data, and (4) submitting both papers for publication. We already have drafts of the studies and will be submitting both papers before the next reporting cycle. For our extension activities, we plan to offer a hybrid organic beekeeping management workshop, where participants will be able to obtain a certificate after the completion of the program. **\*\*Impacts\*\*** What was accomplished under these goals? Below, we report on the specific accomplishments for each goal: Objective 1: Conduct a side-by-side comparison of the impact of three management systems (organic, chemical-free, and conventional) on honey bee colony health. Specifically, we will investigate (1a) colony performance, (1b) immunocompetence, and (1c) parasite and pathogen levels. We completed all the goals of the project. Our results from three years of study indicate that the colonies with organic management have the highest survival, honey production, and the lowest prevalence of the gut parasite *Nosema ceranae* and the virus DWV. In an additional project looking at the impact of miticide applications on the bee bread microbiome, we detected a decrease in the relative abundance of beneficial bacteria such as *Lactobacillus kunkeei* in bee bread after miticide treatment. Objective 2: Quantify cumulative pesticide residues in wax used by bees maintained with different management systems. Wax comb collected from colonies managed under the three management systems (organic, conventional, chemical-free) showed low traces of pesticide residues. Of the 93 agricultural and apicultural chemicals included in the pesticide analysis (<https://blogs.cornell.edu/cccef/the-facility/>), only 23 were detected in any of our samples. The three most common compounds were metolachlor (herbicide), piperonyl butoxide (synergistic compound), and fenpyroximate (miticide used for leafhoppers, mealybugs, other mites), which are all considered "no bee precaution" by the EPA. Results from wax comb pesticide residues collected from colonies foraging on organic land are 100 times lower than the values previously reported for colonies foraging on conventional agricultural land. Objective 3: Conduct a cost-benefit analysis of honey bee management systems to quantify the profitability of each of these systems to beekeepers. We found that the operations following an organic management system are the most profitable. During the last year of the experiment when colonies were established and most productive, colonies managed under the organic management system produced on average 34% and 45% more honey than colonies in the chemical-free and conventional systems, respectively. These differences in honey production resulted in \$238 of income per colony for colonies in the organic system compared to \$165 for colonies in the conventional system. Low overwintering survival in the control (CF) group drastically decreased total honey production and profits over time. Objective 4: Work with the advisory panel on extension activities that will lead to behavioral changes in conventional and organic beekeepers interested in alternative management practices. Since the beginning of the project, we have had close communications with the stakeholder group comprised of 30 experienced beekeepers who use different management practices (chemical-free, organic, conventional). The main goal of these meetings has been to have stakeholder input to develop beekeeping management protocols that would represent how conventional, organic and chemical-free beekeepers manage their honey bees colonies. In addition, we have presented updates about the results of the project. In-person meetings have been followed up by multiple virtual meetings with each group independently. Our goal of having stakeholder input for our project has been successfully accomplished. We used the protocols obtained from these groups for our experiments, and we have been in close communication with them about our results. We recently published an extension publication delineating the details of organic beekeeping management: <https://extension.psu.edu/an-organic-management-system-for-honey-bees> In summary, we have three full years of data and are now completing the data analysis. We are working on two publications; one about the impacts of management on honey bee health and the other on the economics of beekeeping using the three management systems. Our analysis indicates that the organic management system is the most cost-effective management system while also keeping bees healthy. This coming year (2022), we plan to conduct extension activities to teach beekeepers how to manage their bees using organic management practices. Through a 6-section webinar series and in-person workshops, beekeepers will learn all of the details of keeping bees healthy and productive without the use of synthetic miticides.

**\*\*Publications\*\*** - Type: Other Status: Published Year Published: 2021 Citation: Underwood, R. July 2021. An Organic Management System for Honey Bees. Penn State Extension, University Park, PA. <https://extension.psu.edu/an-organic-management-system-for-honey-bees> - Type: Journal Articles Status: Published Year Published: 2021 Citation: Evans KC, Underwood RM, Lopez-Uribe MM. (2021) Combined effects of oxalic acid sublimation and brood breaks on Varroa Mite (*Varroa destructor*) and Deformed Wing Virus levels in newly established honey bee (*Apis mellifera*) colonies. *Journal of Apicultural Research*: 1-9 - Type: Conference Papers and Presentations Status: Accepted Year Published: 2021 Citation: Underwood RM, Kelsey T, Lopez-Uribe M. Jan. 6-7, 2021. *Beekeeping Economics: A comparison of the profitability of conventional, organic and treatment-free management systems* (Oral Presentation) American Bee Research Conference. Virtual. 120 participants - Type: Conference Papers and Presentations Status: Accepted Year Published: 2021 Citation: Lopez-Uribe M, Lawrence B, Underwood RM. Jan. 6-7, 2021. *Longitudinal DWV and immune gene expression dynamics in colonies managed under conventional, organic, and chemical-free systems*. (Oral Presentation) American Bee Research Conference, Virtual. 120 participants **\*\*Progress\*\*** 09/01/19 to 08/31/20 **\*\*Outputs\*\*** Target Audience: Our main targeted audience are beekeepers. One of the great achievements of this project has been the ability to create bridges of communication between beekeepers who manage honey bees using conventional practices and beekeepers who choose to manage bees without the use of chemicals. The latter group has historically been marginalized from mainstream beekeeping meetings because of their ideology for bee management. We have successfully brought together these groups of beekeepers to have open discussions about beekeeping practices. Through over 18 talks and workshops to beekeeping clubs, regional, national and international conferences, we have reached an audience of approximately 10,000 beekeepers and farmers about the topic of our project and the promising results of establishing a protocol to keep bees exclusively under organic treatments. Underwood RM. The three most important steps to ensuring honey bee colony survival over the long term. Penn State Extension Webinar Series, University Park, PA. (June 10, 2020; 1,000 participants). Lopez-Uribe MM. Health Challenges from a Bee's Perspective. Penn State Extension Webinar Series, University Park, PA. (June 3, 2020; 1,200 participants). Underwood, R. Honey Bee Anatomy. For the Lehigh Valley Beekeepers Association, Lehigh Carbon Community College, Schnecksville, PA. (February 20, 2020; 62 attendees) Lopez-Uribe MM. Bees and Pollination 101. Mid-Atlantic Fruit and Vegetable Convention. Hershey, PA USA (January 2020; 40 attendees) Underwood R, M. Lopez-Uribe. Conventional and Organic Management of Bees (COMB) Project: 3rd Stakeholder Meeting, Co-Instructor, Boalsburg, PA (October 31, 2019; 30 registrants). Underwood R, B. Traver, M. Lopez-Uribe. Project COMB: Conventional and Organic Management of Bees. Lancaster County Beekeepers Society, (September 17, 2019; 35 attendees). Underwood R, B. Traver, M. Lopez-Uribe. Project COMB: Conventional and Organic Management of Bees. Lehigh Valley Beekeepers Association, Northampton, PA. (August 22, 2019; 55 attendees). Underwood R, B. Traver, M. Lopez-Uribe. Project COMB: Conventional and Organic Management of Bees. Wayne County Beekeepers Association, Honesdale, PA (August 20, 2019; 62 attendees). Lopez-Uribe MM. COMB Project: Conventional and Organic Management of Bees. Chester County Beekeeping Association, West Chester, PA (March 9, 2019; 40 attendees) Underwood RM, Lopez-Uribe MM. Honey bee health and organic beekeeping management practices. Pennsylvania Association for Sustainable Agriculture (PASA). Lancaster, PA USA (February 2019; 50 attendees) 90 minute workshop Lopez-Uribe MM. Lopez-Uribe Lab: Research and Extension Updates. Horticulture Extension Team Group Meeting. State College, PA USA (April 2018; 50 attendees) Underwood R, Lopez-Uribe MM. Conventional and Organic Management of Bees (COMB) Project: 2nd Stakeholder Meeting, Co-Instructor. (November 30, 2018; 30 participants). Underwood R, Evans KC, Lopez-Uribe MM. COMB Project: Technical training. State College, PA (March 16, 2018; 12 attendees) Underwood, R. Introducing the COMB Project. Treatment Free Beekeeping Conference, Oracle, AZ. (20 participants, 2-4 March 2018) Underwood R, Evans KC, Lopez-Uribe MM. COMB Project: First stakeholder meeting. State College, PA USA (November 17th 2017; 30 attendees) Underwood R. Chemical Free Protocol Follow-up. Skype. (December 7 2017; 5 attendees) Underwood R. IPM Protocol Follow-up. Skype. (December 11 2017; 6 attendees) Underwood R. Conventional Free Protocol. Skype. (December 13 2017; 7 attendees) Changes/Problems: The colonies that survived the winter of 2019-20 were generally strong and managed to prevent swarming by splitting the colonies (removing the queen and some brood to make additional colonies). This resulted in most (almost all) colonies having a brood break and queen replacement at least once in 2020. Unfortunately, about 35% of the colonies did not successfully produce a mated queen, which resulted in the loss of these colonies. This was not something we intended to allow in our management systems. Nevertheless, it was consistent across treatments, so it should not cause a problem with the results. What opportunities for training and professional development has the project provided? We have had the opportunity to train less experienced beekeepers who have been hired as wage employees to work with us on this project. These training opportunities have engaged communities that cannot access online information about beekeeping such as Amish farmers. During this project, they have learned with us how to do advanced beekeeping, and how these different management types differ. We successfully led a 90 minute workshop during the Pennsylvania Association for Sustainable Agriculture (PASA) Meeting where we

talked about the details of organic beekeeping. In addition, one Master's student has been involved with this project. She is involved with the field data and sample collection and she is leading the laboratory analysis for the immune gene expression and viral work as well as the bee bread microbiome study. She is currently also working on developing a 4H curriculum about beekeeping for Penn State Extension. How have the results been disseminated to communities of interest? As mentioned above, we have held three stakeholder meetings throughout the duration of the project. We will hold the last stakeholder meeting in the spring of 2021. We have given 15 talks at local beekeeping clubs reaching an audience of over 350 people. Regionally, beekeepers are aware of our project because of talks at the State Beekeeping Meeting. We send regular updates to beekeepers through our lab listserv (more than 200 subscribers). We have conducted two successful webinars to 2,200 attendees each and we will now work on an additional presentation through eXtension about the findings of our project. What do you plan to do during the next reporting period to accomplish the goals? We will continue our assessments of colony health status through spring of 2021 (objective 1a), analyses of immune gene expression and pathogens are underway (objective 1b and 1c), and the economic analyses of the detailed time and expenditure records will be finalized (objective 3). We also plan to send wax samples for pesticide residue analysis to a testing lab to accomplish objective 2 of the project.

**\*\*Impacts\*\*** What was accomplished under these goals? Since the beginning of the project, we have had close communications with the stakeholder group comprised of 30 experienced beekeepers who use different management practices (chemical free, organic, conventional). The main goal of these meetings has been to have stakeholder input to develop beekeeping management protocols that would represent how conventional, organic and chemical free beekeepers manage their honey bees colonies. In addition, we have presented updates about the results of the project. In-person meetings have been followed up by multiple skype meetings with each group independently. Our goal of having stakeholder input for our project has been successfully accomplished. We used the protocols obtained from these groups for our experiments, and we have been in close communication with them about our results. For the first year of the experiment, efforts were focused on finalizing the establishment of the colonies in the 24 apiaries included in the project. After the first year of the project, we successfully installed 288 honey bee colonies on 8 farms located in northeastern PA, southeastern PA, central PA and western WV. Each region comprises two farms with three apiaries each (for a total of 24 apiaries and 288 colonies). For the success of this project, wage employees with some beekeeping experience have been hired in the various regions. These workers were hired to assist with colony assessments. Colonies were assessed every month to collect data on the levels of the parasitic varroa mites. Each season, spring and summer, bees were collected for lab assays for Nosema disease, viruses, and immune gene expression. Building of wax comb was quantified each month as well. During assessments that simulate a normal beekeeper visit, inspections were timed for use in an economic analysis of each management system. In addition, we have an ongoing project looking at the changes in the microbiota of beebread before and after miticide treatments. Our preliminary results indicate that the colonies with organic management have the lowest prevalence of the gut parasite *Nosema ceranae*. We have found that honey bee colonies treated with organic and synthetic miticides have fewer varroa mites and better winter survival than those left untreated. However, untreated colonies produce significantly more honey than treated colonies. In addition, we have also detected a decrease in the relative abundance of beneficial bacteria such as *Lactobacillus kunkeei* in bee bread after miticide treatment. We have successfully developed protocols to manage honey bee colonies exclusively using cultural and organic chemicals management practices. We are working on developing a better understanding of the variation and effectiveness of different beekeeping management practices on honey bee health. We have demonstrated that variation in management practices among beekeepers is mainly driven by two factors (1) size of the operation and (2) beekeeper's philosophies towards chemical use (Underwood et al 2018). Therefore, there is a clear need for development of best management practices for these different groups of beekeepers. We have two full years of data and are now completing the data collection for year 3 and have begun to analyze the data for the economic analysis of each of the beekeeping management systems. Our preliminary analysis indicates that the organic management system is the most cost-effective management system. This coming year, we also plan to publish two more peer-reviewed publications, factsheets that take beekeeping management philosophy into account when considering pest and pathogen control, and a seminar through eXtension about our project.

**\*\*Publications\*\*** - Type: Journal Articles Status: Published Year Published: 2020 Citation: McAfee, A., Chapman, A., Higo, H., Underwood, R., Milone, J., Foster, L. J., Guarna, M. M., Tarpay, D. R., & Pettis, J. S. (2020). Vulnerability of honey bee queens to heat-induced loss of fertility. *Nature Sustainability*. <https://doi.org/10.1038/s41893-020-0493-x> - Type: Journal Articles Status: Published Year Published: 2019 Citation: Underwood RM, Traver BE, Lopez-Urbe MM (2019) Beekeeping management practices are associated with operation size and beekeepers philosophy towards in-hive chemicals. *Insects* 10: 10 [doi.org/10.3390/insects10010010](https://doi.org/10.3390/insects10010010) - Type: Journal Articles Status: Published Year Published: 2019 Citation: Lopez-Urbe MM, Simone-Finstrom MD (2019) Honey bee research in the US: Current state and solutions to beekeeping problems. *Insects* 10: 22 [doi.org/10.3390/insects10010022](https://doi.org/10.3390/insects10010022) - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Underwood RM, Lawrence B, Kietzman, BE Traver, MM Lopez-Urbe. Management trade-offs of conventional, organic and chemical-free beekeeping

(Poster Presentation) American Bee Research Conference, Schaumburg IL, 9-10 January 2020. (60 attendees) - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Underwood R, B Traver, M Lopez-Urbe. A side-by-side comparison of honey bee health in colonies managed using conventional, organic, and chemical-free systems. Apimondia: International Apicultural Conference. Montreal, Quebec, Canada, 8-12 September 2019. (~1500 audience members) - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Underwood R, B Lawrence, B Traver, M Lopez-Urbe. A side-by-side comparison of honey bee health in colonies managed using conventional, organic, and chemical-free systems. International Pollinator Conference, UC Davis, Davis, CA 17-20 July 2019. Poster. (250 attendees) - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Underwood R, B Traver, M Lopez-Urbe. COMB project (management systems comparison). Alternative Beekeeping Conference, Kerhonkson NY, 25-26 May 2019. (15 attendees) - Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Underwood, R, D vanEngelsdorp, B Traver, and K Nichols. 2018. A side-by-side comparison of honey bee management systems. American Bee Research Conference, Reno, NV. (11-12 January 2018) - Type: Websites Status: Published Year Published: 2019 Citation: Underwood R. November 2020. COMB Update November 2019. (invited blog post November 25th 2019) <https://lopezuribelab.com/2019/11/25/elementor-5997/> - Type: Journal Articles Status: Published Year Published: 2019 Citation: Underwood, R. March 2019. The Beekeeping Continuum: Whats Your Philosophy? American Bee Journal 159:337-339. (approximately 15,000 subscribers) - Type: Websites Status: Published Year Published: 2018 Citation: Underwood R (2018) Project COMB, equipment story (invited blog post May 19th 2018) <http://lopezuribelab.com/2018/05/19/project-comb-equipment-story/> - Type: Websites Status: Published Year Published: 2018 Citation: Underwood R (2018) Protocol for hive irradiation (invited blog post February 14th 2018) <http://lopezuribelab.com/2018/02/14/gamma-irradiation-beekeepers/> - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Underwood R, B Traver, M Lopez-Urbe. What is Alternative Beekeeping - Defining our Methods. Alternative Beekeeping Conference, Kerhonkson NY, 25-26 May 2019. (12 attendees) - Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Traver B, K Alemany, A Hatter, M Stoner, R Underwood, P Kietzman, KC Evans, MM Lopez-Urbe. Examining Nosema spp. in honey bee hives under different management practices (Poster presentation) Entomological Society of America, Vancouver, BC, Canada, November 2018 (3800 attendees) - Type: Websites Status: Published Year Published: 2017 Citation: Underwood R (2017) COMB, Conventional & Organic Management of Bees Stakeholder Meeting (invited blog post November 20th 2017) <http://lopezuribelab.com/2017/11/20/comb-conventional-organic-management-bees/> \*\* \*\*

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# Collaborative Research and Extension Network Addressing Challenges for Sustainable Organic Mushroom Production

<b>Accession No.</b>	1013023
<b>Project No.</b>	PENW-2017-02421
<b>Agency</b>	NIFA PENW\
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26818
<b>Proposal No.</b>	2017-02421
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2020
<b>Grant Amount</b>	\$959,984
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Beyer, D. M.; Gorgo-gourovitch, MA, AC.; Urbanchuk, JO, M.
<b>Performing Institution</b>	PENNSYLVANIA STATE UNIVERSITY, 408 Old Main, UNIVERSITY PARK, PENNSYLVANIA 16802-1505

## NON-TECHNICAL SUMMARY

Mushroom farming is a \$1.1 billion per annum industry in the United States. During the 2015-2016 growing season US mushroom growers produced 91.1 million pounds of mushrooms that were certified organic, 49% more than during 2014-2015 (<http://www.nass.usda.gov>). Sales of certified organic mushrooms were 64.9 million pounds, or 71% of the total organic production, up 57 percent from the 2014-2015 crop year. Agaricus mushrooms accounted for 67 percent of the mushrooms sold as certified organic, while all specialty mushrooms made up the remainder. The certified organic sales of all mushrooms represent 7 percent of the 2015-2016 total mushroom sales. The number of certified organic mushroom growers totaled 68, representing 20 percent of the 346 total mushroom producers. Stakeholders for this project are North American commercial organic mushroom growers and suppliers and the industry organizations that represent them. This research proposal is the direct result of a need identified as part of the 2016 Mushroom industry strategic planning meeting/report and input from organic mushroom growers (<http://plantpath.psu.edu/research/areas/mushroom-science-and-technology/strategic-planning-reports/2016-strategic-planning-meeting-report>). Organic mushroom production is particularly susceptible to attack by fungal and bacterial diseases, and fly infestations due to lack of OMRI approved products registered for use in mushroom production, this results in reductions in yield, quality and shelf life of the product. These issues, along with the higher cost of organic approved compost components and increased administration costs required for traceability of organically produced mushrooms seriously affect the economic viability of organic mushroom production. This research program aims to develop tools and strategies for adoption by organic growers that address these issues and increase profitability. In collaboration with eOrganic and eXtension, we will develop an interactive online presence for communication of project results to the organic growers and their allied industry parties. We will be conducting extensive outreach efforts to facilitate grower adoption of the findings, through articles in the trade magazine Mushroom News, industry conferences, workshops and extension publications such as grower fact sheets and web site updates in English and Spanish. Additionally, we will be training undergraduate students from Penn State University to be familiarized with the mushroom industry, providing the next generation of researchers and technical growers.

## OBJECTIVES

The development and improvement of organic mushroom production. (30%) Evaluating the potential economic benefits of organic agricultural production and methods to producers, processors and rural communities. (20%) Identifying marketing and policy constraints on the expansion of organic agriculture. (10%) Conducting advanced on-farm research and development that emphasizes observation of, experimentation with, and innovation for working organic mushroom farms, including research relating to production, marketing and farm business management. (30%)

## APPROACH

The fungal pathogens and a commercial hybrid strain of *A. bisporus* will be grown in triplicate in 5-cm dia. petri plates containing potato dextrose yeast agar (PDYA) medium (Difco) amended with 5 to 50  $\mu\text{L/L}$  active ingredient of an essential oil. The mean diameter of the cultures will be determined after 3-10 days and 2-3 wks of growth at 24C for the fungal pathogens and *A. bisporus*, respectively. Fungicides inhibiting the radial growth of the pathogens without significant toxicity to the mushroom fungus will be advanced to the next phase, cropping trials. Fungal pathogens will be introduced with a spore suspension sprayed on the surface of the casing. The incidence and severity of disease development will be measured and the data statistically analyzed. We propose to: A) conduct isolation based surveys of the microbiome of healthy and diseased organically grown mushroom caps; B) develop cocktails of strains for prophylactic and curative application to prevent and inhibit spread of blotch disease; and C) develop and use quantitative PCR to monitor pathogen population changes in organic production systems as a first step to development of a prediction system for optimal application of the microbial cocktails. Efficacy of each product will be determined by successful emergence of adult flies from compost artificially infested with sciarid or phorid eggs from our laboratory colonies. Similar protocol will be employed to evaluate the efficacy of commercially available predatory mites and nematodes. Products demonstrating significant population control in laboratory screening will be promoted to semi field trials, where biopesticide applications will be conducted during spawning in the Penn State Mushroom Research Center. These cropping trials will include evaluation of efficacy for fly control and (lack of) toxicity to the mushroom crop. Efficacy and phyto-toxicity data will be provided to the registration holders to support their regulatory applications for label extension for use in mushroom production. Information on new products and use strategies will be disseminated to the wider industry via the extension objectives outlined in this proposal. In studies to isolate and identify attractants from these fungal species as well as from spawned and unspawned compost, we will collect several-hour-long airborne samples from the headspace of these natural substances using Super-Q or Tenax adsorbant traps, extract these adsorbants with hexane, and perform combined gas chromatographic-electroantennographic analyses using female antennae on the samples in order to find potentially behaviorally active attractant compounds emitted from these sources. We will follow up to see if any single compounds eluting from the GC might cause detectable and consistent behavioral activity in females that may later prove, in Y-tube olfactometer bioassays, to be involved in attraction from a longer distance. We propose to grow mushrooms in substrates produced from organically grown wheat straw, organically grow grass hay as well as conventionally grown straw and hay that will receive typical herbicide and fungicide applications according to label rates. This hay and straw will be produced at Penn State University's Plant Pathology farms so that we can control the chemical application rates. Once harvested, these materials will be used to make substrate at Penn State University's Mushroom Research Center following standard mushroom cropping procedures. Yield analyses and mushroom residue levels will be evaluated for the individual treatments to determine if the mushrooms take up any of the pesticides utilized under conventional management practices as well as to determine if use of these chemicals has any impact on yields. We will develop videos and fact sheets in both English and Spanish and on-farm trainings will be conducted. We will use this research to introduce undergraduate students to organic agricultural research through work on projects. Evaluation of the bacterial cocktails will be made on cooperating organic farms in the second or third break when there was significant blotch in the first break. The experiments will be set up and percent disease and population levels will be analyzed as completely randomized designs with five replications. Efforts include acts or processes that deliver science-based knowledge to people through formal or informal educational programs. Examples include: formal classroom instruction, laboratory instruction, or practicum experiences; development of curriculum or innovative teaching methodologies; workshops; experiential learning opportunities; extension and outreach. A completed Summit model provides an analysis of the utility of a proposed technology in the context of one or more scenarios, and allows the user to compare the utility of different technologies in similar contexts. It also allows modelers to reuse contexts, scenarios, task analyses, and interaction models as the basis for assessing the utility of new or alternative technologies for similar application contexts. Our analysis will concentrate on the economic and financial impacts of organic mushroom production. Initially this will involve development of an enterprise budget for *Agaricus* mushroom production as a baseline. We then will examine the impact of the use of organic inputs on mushroom output, costs of production, grower profitability and ultimately consumers. In order to estimate the cost implications of organic mushroom production. The process of constructing the models will require direct engagement with stakeholders to properly define the scope of the models, set clear objectives,

identify constraints, validate assumptions, establish data requirements, and clarify solution quality criteria. If successful, the resulting models will provide decision makers with a robust framework to compare and select alternatives for sustainable substrate raw material procurement and production process planning. **\*\*Progress\*\*** 09/01/17 to 08/31/22 **\*\*Outputs\*\*** Target Audience: North American Mushroom Industry Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? High school and undergraduate students were trained in isolating and identifying bacterial isolates. Mushroom farm employees were trained in organic disease and pest management. We conducted several pieces of training during pesticide meetings in the Spring and Fall of 2019, 2020, 2021, and 2022. How have the results been disseminated to communities of interest? The programming for the last two years is listed below: January 28, 2021 - Phorid Fly Townhall Mike Wolfin (presenter), Nina Jenkins, Tom Baker, and Maria Gorgo Virtual town hall requested by Rep. Sappey, John Lawrence, Craig Williams, and Senator Carolyn Comitta. The goal was to provide the public an update on the progress that has been made in addressing phorid flies. Attended by PA Dept. of Agriculture Russel Reading and Fred Strehmeyer March 18, 2021 - 2021 Spring Virtual Mushroom Pesticide Meeting English session: 09:30 am to 12 pm; Spanish session: 01:00 pm to 03:30 pm; Each session had 5 presentations April 7, 2021 - Phorid fly webinar. Mike Wolfin, Maria Gorgo, and S. Shirk Title: Mushroom Phorid Fly Control - April 2021 Update October 3, 4, and 5, 2021 - Mushroom Short Course Spanish session - Maria Gorgo (Chair, moderator, and speaker) Phorid Fly Research & Extension Update\*- Maria Gorgo and Michael Wolfin, Penn State; Mushroom Production App / The Updated Mushroom Industry Food Safety Training Kit - Sergio Nieto-Montenegro; Post-Harvest Sanitation Best Practices - Javier Lopez, Mother Earth, Inc.; Labor Saving Techniques - Fidel Urbina - Giorgi Mushroom Company October 14, 2021 - 2021 Fall Virtual Mushroom Pesticide Meeting English session: 09:30 am to 12 pm; Spanish session: 01:00 pm to 03:30 pm; Each session had 5 presentations March 24, 2022 - 2022 Spring Virtual Mushroom Pesticide Meeting English session: 09:30 am to 12 pm; Spanish session: 01:00 pm to 03:30 pm; Each session had 5 presentations April 25, 2022 - Phorid fly webinar Mike Wolfin, Maria Gorgo. Remarks by B. Hales, Maryan Molonsly, Rep Christina Sappey, and Fred Strathmeyer. Title: Mushroom Phorid Fly Control - April 2022 Update 106 registered with 60 people watching live and 12 views on the website as of June 2022. There were 348 unique pageviews for the main Webinar Group (both April 7, 2021, and April 25, 2022). October 25, 2022 - 2022 Fall Virtual Mushroom Pesticide Meeting English session: 09:30 am to 12 pm; Spanish session: 01:00 pm to 03:30 pm Each session had 5 presentations What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **\*\*Impacts\*\*** What was accomplished under these goals? Objective Disease Management We investigated spore load and timing of infection for Lecanicillium Dry Bubble disease. The results of this experiment support those of previous studies that dry bubbles form when Lecanicillium infestation occurs in the early stages of sporophore development. When inoculum is introduced to the developing primordium, or even before pin formation, the maturation process is interrupted with either no further development or the appearance of shapeless tissue mounds known as dry bubbles within 12 - 22 days. If the developing sporophore is infested, necrotic lesions and stipe blowouts occur as development continues. Both symptoms are visible within 4 - 9 days of Lecanicillium spore introduction. If infestation occurs later in sporophore development, dark brown spotting of the pileus is visible within 4 days. If Lecanicillium spore exposure occurs just before harvest time, the mushrooms could be symptomless when they are picked. However, the symptoms continue to develop and often render the product unmarketable by the time it reaches the retailer. To better understand the diversity of pathogens that can incite blotch, we have employed a two-pronged strategy. First, we've utilized a high-throughput bacterial isolation system to recover 720 isolates from blotch lesions of commercially grown mushrooms. Of these isolates, 600 were found to be pathogenic when inoculated onto healthy mushrooms. All isolates were fluorescent Pseudomonads and are currently being identified through sequencing of the rpoD marker gene. In addition to characterizing the diversity of blotch pathogens through isolation and Koch's postulates, we have followed up on our previous amplicon sequencing-based approach to identify organisms enriched in diseased mushroom caps compared to healthy mushroom caps. To do this, we've used shotgun metagenomics, which has given us a higher degree of specificity in determining the organisms that are present. Thus far we have shown that *P. tolaasii* is the most over-represented Pseudomonad in diseased compared to healthy mushroom caps. These results have confirmed that *P. tolaasii* is the major blotch-inciting species on Pennsylvania farms. In seeking to develop methods to control blotch that are compatible with organic production systems, we have isolated and purified 12 phages, which target the diversity of Pseudomonas pathogens so far recovered from Pennsylvania farms. Most of these phages are specific in their host range (only targeting the host against which it was isolated), however, there is one phage that can target pathogens from different clades, indicating it has a broader targeting spectrum. In assessing the ability of these phages to inhibit the pathogen population in a mushroom cap setting, we've found that at least one phage leads to significantly reduced populations of the co-inoculated pathogen. Additionally, this phage resulted in the complete absence of disease symptoms three days after inoculation, whereas disease was observed for the pathogen-only inoculation. We will repeat this experiment and then submit these results for publication. Finally, we've recovered isolates of 5 distinct blotch-inciting pathogens (representing distinct pathogenic clades) that have been marked with different antibiotic resistances

(gentamycin and rifampicin). With these strains in hand, we will now be able to perform competition experiments in the mushroom cap environment to determine whether bacteriocins can mediate competitive exclusion between blotch pathogens. Objective: Mushroom Phorid Flies and Sciarid Fungus Gnats EcoVia WD was identified as an effective adulticide in previous pesticide screening assays as promising adulticide. EcoVia WD is FIFRA 25 (b) exempt and approved for use in organic agriculture. The practical application of fine insecticidal dust on mushroom farms was difficult due to the humid and turbulent nature of growing rooms. Therefore, aerosol formulations of essential oil pesticide products were screened for efficacy against adult *Megaselia halterata* (mushroom phorid fly) and *Lycoriella ingenua* (sciarid gnat). Pesticides were retested after 14 days residual period in a fume hood. EcoVia CA was an effective adulticide for both fly species. After a 14-day residual period, EcoVia CA remained effective against *L. ingenua* adults at 0 min, 1 h, and 24 h post-exposure, but effectiveness against *M. halterata* had diminished mortality at 0 min, 1 h, and 24 h post-exposure. Application strategies will be assessed using EcoVia CA in future field studies to control both flies' populations. Since January 2021, we recruited 17 additional growers in Chester County for the implementation of the novel strategy. Growing protocols and farm architectures vary widely from farm to farm, and the management strategies are highly dependent on these variables. We have worked closely with these growers to adapt and customize the implementation of the control methods for individual farms. Optimization of control methods requires consistent monitoring of fly populations and observations of fly behavior to inform adjustments to protocols to ensure consistent control. Fly counts during spawn runs were significantly lower on farms using attract and kill stations compared to those using attract and kill stations across the growing season. Chemical, electrophysiological and behavioral assays were conducted and analyzed to identify the putative sex pheromone components of *M. halterata* and *L. ingenua*. Further research involving final chemical analyses and behavioral assays is being conducted to finish the precise chemical characterization of these two sex pheromones. Additionally, non-pheromonal chemical and visual attractants have been implicated in creating novel attract-and-kill technologies. Pesticide studies indicated possible repellency or behavioral antagonism by essential oil pesticide products. Additional laboratory and field studies are necessary to characterize the behavioral responses to essential oil products in the laboratory and on farms. If essential oil products are effective repellents or behavioral antagonists, these can be effective sustainable methods for control on mushroom farms. Objective Technology App for Traceability The focus of our work during the 2021-2022 project year has been continued testing, refinement, and redesign/development of core CropSmarts features. A second priority this past year has been on the design, development, and testing of an approach to automating crop data capture using sensor and internet-of-thing (IoT) technologies. Accomplishments this year were redesign, development, and testing of many of the application workflows in response to feedback from user testing and public application demonstrations e.g., creating farm topologies, creating crop plans, creating and managing alert values for crop measures. Design, development, and testing of an enhanced organic tracing approach for crops. This provides growers with a simple model for tracking organic and conventional crop inputs. Design, development, and testing of an enhanced crop data export feature to support the use of third-party tools for crop data analytics. Inclusion of organic crop input percentages as part of the crop summary view. Design, development, and testing of an enhanced approach to measuring and viewing crop data captured at the growing room section level. Design, development, and testing of a 3-dimensional spatial view of crop measure data within growing rooms. Design, development, and testing a proof-of-concept architecture for automating the capture of crop operations data using commercial-off-the-shelf (COTS) sensors and internet-of-things technologies. This work has created a foundational infrastructure for the future integration of advanced sensor technologies. Conducted a security audit of the applications and implemented security enhancements in response to findings. ? \*\*Publications\*\* - Type: Websites Status: Published Year Published: 2022 Citation: 1. Syzygites Disease on the Agaricus Mushroom English: <https://extension.psu.edu/basic-ipm-practices-for-organic-mushroom-farms-syzygites-disease-on-the-agaricus-mushroom> Spanish: <https://extension.psu.edu/practicas-basicas-de-mip-para-fincas-de-champi-ones-hongos-organicos-enfermedades-producidas-por-syzygites-en-hongos-agaricus> - Type: Websites Status: Published Year Published: 2022 Citation: 2. Phorid Fly Control English: <https://extension.psu.edu/mushroom-phorid-fly-infestations-in-mushroom-farms-and-surrounding-neighborhoods> Spanish: <https://extension.psu.edu/infestaciones-de-moscas-foridas-del-champinon-en-fincas-productivas-de-hongos-y-barrios-residenciales-cercanos> - Type: Websites Status: Published Year Published: 2021 Citation: 3. What is Integrated Pest Management? IPM for mushroom farms English: <https://extension.psu.edu/basic-ipm-practices-for-organic-mushroom-farms-what-is-integrated-pest-management> Spanish: <https://extension.psu.edu/practicas-basicas-de-mip-para-fincas-de-champinones-hongos-organicos-que-es-el-manejo-integrado-de-plagas-mip> - Type: Websites Status: Published Year Published: 2021 Citation: 4. Bacterial and Viral Diseases of Mushrooms English: <https://extension.psu.edu/basic-ipm-practices-for-organic-mushroom-farms-bacterial-and-viral-diseases-of-mushrooms> Spanish: <https://extension.psu.edu/practicas-basicas-de-mip-para-fincas-de-champi-ones-hongos-organicos-enfermedades-bacterianas-y-virales-de-los-champi-ones-y-hongos-1> 4. Bacterial and Viral Diseases of Mushrooms English: <https://extension.psu.edu/basic-ipm-practices-for-organic-mushroom-farms-bacterial-and-viral-diseases-of-mushrooms> Spanish:

champi-ones-hongos-organicos-enfermedades-bacterianas-y-virales-de-los-champi-ones-y-hongos-1 - Type: Websites Status: Published Year Published: 2021 Citation: 5. Mushroom Fungal diseases English: <https://extension.psu.edu/basic-ipm-practices-for-organic-mushroom-farms-fungal-diseases-of-mushrooms> Spanish: <https://extension.psu.edu/practicas-basicas-de-mip-para-fincas-de-champi-ones-hongos-organicos-enfermedades-fungicas> \*\*Progress\*\* 09/01/20 to 08/31/21 \*\*Outputs\*\* Target Audience: The North American organic mushroom farms and producers. Non-organic mushroom farms would also benefit from this project. Changes/Problems: Mobile app development will focus on pest and disease monitoring, supply chain tracking has not been possible. Fungal pathogen work has and will focus on the new pathogen *Syzygites*. Bio-fungicide testing will continue if new products can be identified. What opportunities for training and professional development has the project provided? Some initial farm and undergraduate trainings were started until COVID stopped those activities. How have the results been disseminated to communities of interest? Yes, several articles were published in the mushroom trade magazine. Reports and information has been presented at Pesticide Credit meeting and the Mushroom Short Courses. What do you plan to do during the next reporting period to accomplish the goals? Complete extension publications and videos. Undergraduate training. Further screening of bio-pesticides for fungal and fly control. Continue mobile app development. Bacterial Blotch Lab To be completed in 3 months Strains will be engineered for bacteriocin competition assays final phage will be isolated. Pathogen diversity paper to be submitted To be completed in 6 months Bacteriocins will be identified from genomes Pathogenicity of strains from GALT samples will be completed To be completed in 9 months Non-ribosomal peptide synthases will be identified from genomes To be completed in 12 months Bacteriocin paper will be submitted Phage paper will be submitted GALT paper will be submitted \*\*Impacts\*\* What was accomplished under these goals? Impact Our project has provided organic mushroom growers with educational materials for their employees to better understand pest and disease control. This research program has developed additional tools and strategies for organic growers to control their pest and disease challenges. This has resulted in improved yield, quality, and fresh mushroom shelf life on organic farms. We have shown the potential to reduce fly populations by 50-99% which increased yield on one farm by over 25%. We also have documented the higher costs of organically produced mushrooms that affect the economic viability of organic mushroom production. Objective 1 We have developed a poster, three videos and five factsheets, all are and or will be available in Spanish. We conducted IPM bilingual trainings for organic mushroom production at the 2021 Mushroom Short Course and several trainings during pesticide meetings in the 2020 and 2021. On-farm IPM training for bilingual employees has been postponed due to the pandemic. Objective 2 Because of COVID disruptions this objective was modified to include a project and an introductory plant pathology class. The project was designed during the 2020 reporting cycle and will be carried out in fall 2021 this should lead to a short manuscript that can be used by high school instructors for isolating in characterizing mushroom pathogens from grocery store mushrooms. Objective 3 We have tested over two dozen biofungicides in-vivo and in-vitro. 6 compounds tested showed no control of Dry Bubble. The epidemiology and etiology of a new pathogen *Syzygites* was investigated looking at inoculation methods and the resulting infection levels. Infection only occurred when inoculating knock-over mushrooms with agar plugs before first break with additional pathogen spread was then observed to healthy mushrooms suggesting the importance of cleaning dead mushroom tissue off the beds. Objective 4 We have sampled blotch disease lesions originating from mushrooms sampled from PA farms using both conventional and a high throughput isolation system, recovering ~800 isolates. Using this same approach, an additional 870 bacterial isolates were obtained from diseased mushrooms from three organic farms in CA. We are currently working to identify those that are pathogenic. We suggest that bacteriocin production by pathogens may help to determine which pathogens dominate in any given site. We have generated strains of six different pathogens that are resistant to 2 antibiotics. We have isolated an additional 8 bacteriophages that are able to infect various blotch-causing pathogens. We now are defining the host range for each phage to make sure that the collection covers the entire diversity of pathogens isolated. Objective 5 Several OMRI listed control products were screened for efficacy against *Megaselia halterata* (phorid fly) and *Lycoriella ingenua* (sciarid fly). Screening activities identified EcoVia WD as a promising adulticide and is approved for use in organic agriculture. The application of EcoVia WD as a perimeter treatment reduced populations by 50%. We have been developing an application strategy that exploits the observed behavior of flies and their attraction to light. We evaluated the efficacy of EcoVia WD using electrostatic screens as a pesticide delivery system in windows vents in mushroom growing rooms. A practical integrated pest management program (IPM). strategy was developed to exploit the behavioral ecology of adult *M. halterata* by creating attract and kill stations in the growing rooms. Objective 6 Assays were conducted to identify the putative sex pheromone components of both fly species. Further research is being conducted to find the precise chemical characterization of these two sex pheromones. The electrostatic screening described above was used to replace the old window filters, and so now more light is let into the rooms creating a stronger and more attractive visual cue for the flies. Further studies are necessary to identify the volatile components of growing mycelia to identify the behaviorally active compounds to develop monitoring traps and kill stations. Objective 7 To test for residue levels and the effects of pesticide usage on mushroom substrate raw materials, organic wheat straw was used in comparison with conventionally grown wheat straw. Three pesticides

were applied during the summer growing season to the conventionally grown wheat according to recommended label rates: Caramba &reg; (metconazole), Harmony &reg; Extra (thifensulfuron methyl) and Roundup (glyphosate). Two substrates were prepared at the Mushroom Research Center, one utilizing the organic wheat straw and one utilizing conventionally grown wheat straw. Straw samples of both were sent to a lab for chemical residue analyses. Mushrooms were then grown on each substrate and were harvested for 2 breaks and crop yield was assessed for each treatment. Mushrooms were collected and pooled separately from the 1st and 2nd breaks and then sent for residue analyses. No detectable levels of the either of the herbicides (Harmony Extra or Roundup) were detected in in the straw or in any of the mushrooms sampled from cropping. Caramba levels were detected in the conventionally produced straw but was not in the mushrooms harvested on the conventional straw-based substrate. No statistical differences in mushroom yield were observed. Objective 8 Two CropSmarts applications; a web-based application for managing farm and crop configurations and a mobile app for crop inputs, measures, and outputs was user tested. Progress was made on furthering the functionality and usability of the 2 applications. A proof-of-concept sensor suite for automating capture of crop variables was tested during at least 10 Zoom-based meetings with project stakeholders. An extended trial with one grower was conducted. The web application is available to test at: <https://www.cropsmarts.com/>. Objective 9 . A set of industrywide surveys was designed in a joint effort between Delaware Valley University and Penn State University to capture aggregate level volumes and expenditures and assess demand uncertainty, supply risk, and the strengths and weaknesses of links along the business to consumer (B2C) mushroom supply chain. The objectives during this phase were to: (1) analyze the economic and financial impacts of organic mushroom production in comparison to conventional production, and (2) identify the organic mushroom supply chain effects observed from a demand and supply planning standpoint. The survey was sent to 94 mushroom growers who accounted for 28% of U.S. mushroom production and accounted for nearly 60% of total organic mushroom production. Survey responses indicate that organic mushroom yields averaged 6.8% below conventional yields and the cost of producing organic mushrooms is estimated to be 19% above that reported by conventional growers. Labor costs and compost are the two highest operating costs for organic growers. Consumer interest in organic mushrooms continues to increase and is creating opportunities and higher profits for growers. A survey of mushroom growers indicates that cash operating costs for organic mushrooms are nearly 20% higher than those experienced by conventional mushroom production. However, consumers have spent 45% more on fresh organic mushrooms than on equivalent conventional mushrooms. The answer to whether the additional costs associated with organic mushroom production are justified in the market is a resounding yes. \*\*Publications\*\* - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Using the Prospector System (TM) for high-throughput isolation and identification of mushroom blotch pathogens. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Not all Viruses are Bad: Controlling Mushroom Blotch Disease with Bacteriophages - Type: Journal Articles Status: Published Year Published: 2020 Citation: USDA-NIFA Organic Research and Extension Initiative Project, 2019 Update - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Update on Syzygites Research - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Mushroom Madness: The Carnival of Pathogens Causing Bacterial Blotch on Mushrooms and Strategies for Blotch Management - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Use of attract and kill stations to control mushroom phorid flies on mushroom farms - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Use of essential oil products and natural attract and kill stations to control mushroom fly populations - Type: Other Status: Published Year Published: 2021 Citation: Overview of management strategies for mushroom phorid flies - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Advances in mushroom fly control on mushroom farms - Type: Websites Status: Published Year Published: 2021 Citation: Steam-Off and Post-Crop Pasteurization to Maintain Low Pest Population on Organic Mushroom Farms - Type: Websites Status: Published Year Published: 2021 Citation: What is IPM and How to Use Cultural Control Practices to Minimize Pest and Disease Problems on Organic Mushroom Farms - Type: Websites Status: Published Year Published: 2021 Citation: Interactions of Sciarid Fly Larvae and Biocontrol Nematodes - Type: Websites Status: Published Year Published: 2021 Citation: Syzygites Disease on the Agaricus Mushroom - Type: Websites Status: Published Year Published: 2021 Citation: Phorid Fly Control - Type: Websites Status: Published Year Published: 2021 Citation: What is Integrated Pest Management? IPM for organic mushroom farms - Type: Websites Status: Published Year Published: 2021 Citation: Bacterial and Viral Diseases of Mushrooms - Type: Websites Status: Published Year Published: 2021 Citation: Mushroom Fungal diseases \*\* \*\*

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# Breeding Organic Cotton Cultivars with Distinct Morphological Marker for Purity Maintenance

<b>Accession No.</b>	1013034
<b>Project No.</b>	TEX09697
<b>Agency</b>	NIFA TEX\
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26812
<b>Proposal No.</b>	2017-02519
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2021
<b>Grant Amount</b>	\$783,237
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Dever, J. K.; Hague, ST, .; Kelly, CA, .; Byrd, SE, .
<b>Performing Institution</b>	TEXAS A&M UNIVERSITY, 750 AGRONOMY RD STE 2701, COLLEGE STATION, TEXAS 77843-0001

## NON-TECHNICAL SUMMARY

This project addresses OREI priority (4) to strengthen organic crop seed systems and plant breeding for organic production, with an emphasis on publically available releases. Cultivars with simply-inherited, co-dominant leaf shape distinct from commercial GE cotton cultivars will be developed for organic production. Commercial planting seed suitable for organic cotton production is limited because seed companies have shifted away from producing non-GE seed and such seeds are becoming more difficult to acquire. Conventional, non-GE cultivars were not developed for, and are not well adapted to, organic production. Organic cotton farmers save planting seed of obsolete cultivars, no longer commercially available without GE traits, under the PVPA farmer exemption. Farmers seeking to transition to organic production do not have access to seed under the 1994 restriction to this exemption. The major constraint to organic saved cotton seed for planting is unintended adventitious presence of GE traits. Breeding lines developed at Texas A&M AgriLife Research with stakeholder-defined objectives host plant resistance to thrips, disease resistance, low leaf pubescence, efficient plant architecture, drought tolerance, and enhanced fiber quality are included in a complex crossing scheme with okra-leaf shape sources. Studies will be conducted to investigate impact of leaf shape on other organic production considerations. The distinct leaf shape, visible prior to flowering, can be used to manage outcrossing and physical, mechanical contamination. GE avoidance and mitigation training using the okra-leaf marker will be provided. Project objectives address legislatively-defined goal (8), developing new and improved seed varieties particularly suited for organic agriculture.

## OBJECTIVES

Long-term goal of this project is to sustain integrity of U. S. organic cotton production with high quality, organic-appropriate cotton cultivars homozygous for the okra-leaf trait, to avoid and mitigate adventitious presence (AP) of genetically engineered (GE) traits not approved in cultivars for organic production. Specific objectives of this project are to 1) develop publically available okra-leaf cotton cultivars appropriate for organic production systems (Dr. Dever); 2) compare leaf trash content of okra-leaf and normal leaf lines with varying pubescence (Dr. Byrd); 3) evaluate utility of existing okra-leaf sources as parental material and for organic production outside the West Texas region (Dr. Hague); 4) conduct fiber analysis and spinning trials on candidate okra-leaf lines (Dr. Kelly); 5)

train organic cotton farmers on GE avoidance and mitigation measures using visual screening; 6) develop transformational curriculum for undergraduate and continuing education students. These objectives address long-term goals of developing appropriate cultivars, maintaining sustainable organic fiber markets, and preserving integrity of U. S. organic cotton.

## APPROACH

Large, segregating populations will be developed via forced complex cross pollination with parental sources identified as appropriated for organic cotton production, and available okra-leaf accessions. Individual F2 generation okra-leaf plants will be analyzed for fiber quality, with an expected 10% selection intensity. F3 progeny rows will be rogued for leaf shape, sampled for fiber quality, and advanced to F4 progeny rows. F4 progeny rows selected for multi-location, small-plot replicated performance testing will be screened for disease resistance, boll type, abiotic and biotic stress tolerance. Eight cultivars, four okra leaf, and four normal, with four levels of leaf pubescence ratings within each leaf shape, will be identified using leaf hairiness index developed by Morgan, et al. (2015). Trials will be planted in 2-row plots, 10-12 m long, 1 m row width in two locations utilizing a completely random 2X2 factorial design with four replications. Leaf hair index will be recorded during each of two growing seasons, and each cultivar will be photographed to document leaf shape. Fiber from boll samples and grab samples will be sent to the USDA-AMS Lubbock classing office for leaf grade determination. The cultivar development approach proposed requires large segregating F2 populations to enhance probability of comprising a successful organic cultivar with the okra-leaf trait. Previous research shows fiber quality values from F2 individual plants is predictive of later generation quality (Kelly et al. 2013). Fiber quality is inherently variable and individual plant selection in the F2 generation, as opposed to bulk selection, results in more uniformity within a cultivar's individual fiber properties. Fiber analysis by HVI is objective, relatively quick and cost-effective. A new course, 'Organic Crop Production Systems,' will be created and upon approval will be taught yearly or more often if enrollment demand is high. The course will be offered as a standard course as well as in a distance delivered format with closed captioning for the hearing impaired. From these revised and new courses, teaching modules will be offered through the Texas A&M University's Plant Breeding academy which offers courses to individuals seeking short courses in plant breeding related topics. \*\*Progress\*\* 09/01/17 to 08/02/22 \*\*Outputs\*\* Target Audience: Organic cotton growers, ginners, and seed companies engaged in non-GE commercial cotton cultivar development are the primary target audience for candidate cultivar development objectives, any post-harvest processing issues, and planting seed production. Secondary target audience is public cotton breeders and cotton research scientists involved in enhancing genetic diversity; and organic brands, manufacturers and suppliers. Partners with interaction throughout the project include Plains Cotton Growers, Lamesa Cotton Growers, Cotton Incorporated, Organic Cotton Accelerator, Textile Exchange, Global Organic Textile Standards, King-Mesa Gin, O&#39;Donnell Coop Gin, Meadow Coop Gin, Americot, Brownfield Seed and Delinting, May Seed Company, and Texas Organic Cotton Marketing Cooperative. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?With Texas A&M Extension Organic Production Specialist, seminars (2021) and field days (2022) were conducted to train and consult with farmers on seed issues such as purity maintenance, processing exemption clarification, and different mechanisms for contamination potential inorganic cotton production. How have the results been disseminated to communities of interest?Graduate students, PD, and Co-PDs attend Beltwide Cotton Research Conference and ASA-CSSA-SSSA each year of the project, presenting latest information on research conducted in each objective. Descriptions of cultivar releases funded by this project are published in the Journal of Plant Registrations. Individual meetings were held with seed companies developing and/or commercially producing non-GE cotton varieties. At least one field day associated with organic cotton production and seed development was held each year of the project (virtually in 2020 and 2021). What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported \*\*Impacts\*\* What was accomplished under these goals? Two okra-leaf cotton cultivars appropriate for organic production systems were developed, registered, released, and seed deposited in the National Plant Germplasm System and National Cotton Germplasm Collection. Disclosures and Material Transfer Agreements prepared with company interested in developing non-GE varieties for organic production. Final results of leaf trash content study are presented to farmers concerned about okra-leaf trait on cotton grades. Fiber quality of new okra-leaf germplasm is comparable to quality of normal-leaf cultivars currently used in most US organic cotton production. An additional okra-leaf cultivar candidate is in final year of multi-location replicated testing and seed increased free from GE exposure in a dedicated greenhouse bay. This seed will be used to train organic farmers on GE avoidance and mitigation while producing planting seed for their farms or under contract with a seed company. A new course in organic crop production (SCSC 489) was developed at Texas A&M University Department of Soil and Crop Sciences. \*\*Publications\*\* - Type: Journal Articles Status: Published Year Published: 2022 Citation: Maeda, A. B., C. M. Kelly, V. A. Morgan, S. Hague, Z. C. Wyatt, and J. K. Dever. 2022. Registration of CA 4014 and CA 4015 cotton cultivars. Journal of Plant Registrations. 16(2), 205-211. <https://doi.org/10.1002/plr2.20216>. - Type: Other Status: Published Year Published: 2022

Citation: Dever, J. K., V. Morgan, C.M. Kelly, A. B. Maeda, T. A. Wheeler, K. Stair, and M. M. Maeda. 2022. Cotton performance tests in the Texas High Plains, 2021. Texas A&M AgriLife Research Technical Report 22-2. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Wilson, B. R., J. K. Dever, C. M. Kelly, S. Hague, and S. A. Byrd. 2022. Effect of leaf and bract pubescence on fiber quality of normal and okra leaf cotton. Proceedings of the Beltwide Cotton Research Conference. National Cotton Council of America. - Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: Johnson, J., S. Hague, J.K. Dever, and G. Sword. 2022. Influence of flower openness on yield in cotton [Abstract]. ASA, CSSA, SSSA International Annual Meeting, Baltimore, MD.

<https://scisoc.confex.com/scisoc/2022am/meetingapp.cgi/Paper/143190> \*\*Progress\*\* 09/01/20 to 08/31/21

**\*\*Outputs\*\*** Target Audience:Organic cotton growers (3) and ginners (1) were engaged regarding candidate cultivar releases and options to assist with selecting lines to go forward for seed production. Public cotton breeders and cotton research scientists involved in enhancing genetic diversity; companies involved in non-GM cotton seed breeding and development; organic cotton producers on the Southern High Plains. Partners with interaction during reporting period include Plains Cotton Growers, Cotton Incorporated, Organic Cotton Accelerator, Textile Exchange, Global Organic Textile Standards, Americot, Brownfield Seed and Delinting, and Texas Organic Cotton Marketing Cooperative. Texas A&M hired an Extension Organic Production Specialist, Bob Whitney, in June 2020. We have established contact and he is organizing extension and information session in which we will participate. Changes/Problems:A planned candidate cultivar demonstration with GPS coordinates for farmers to view at their convenience (in absence of group field days) with QR codes to multi-year, multi-location data was destroyed by tornado and hail damage. Seed increase blocks in another location were also damaged but still stand though quantities may be limited. Fiber will also be too limited to perform spinning trials, so advancement to commercial stage will be based on fiber properties only. Publication of cultivar registration manuscript is delayed. Another graduate student, Joshua Johnson, is being supported by the project after Martin Costa's early departure. Thus, a one-year extension of this project was requested and approved. What opportunities for training and professional development has the project provided?Graduate student Bradley Wilson virtually attended and presented project results at the Beltwide Cotton Research Conference in January 2021 and won first place in the graduate student competition. How have the results been disseminated to communities of interest?Nursery and test results were reported at the annual meetings of the Plains Cotton Improvement Program board and Texas Organic Cotton Marketing Cooperative and biannually to the project advisory board. Data for candidate organic cotton cultivars was provided to potential seed company partners. Course syllabus SCSC 489 is published in the Texas A&M University undergraduate catalog. What do you plan to do during the next reporting period to accomplish the goals? Candidate cultivars planted in demonstration plots for organic farmer input was lost to tornados and hail damage, so it will be repeated in 2022. If 2021 seed increase is productive, lines most appropriate for organic cotton production will be available for demonstration plots on certified organic farms and breeder seed increase for transferring to planting seed production partners. Graduate student Bradley Wilson, Oklahoma State, will continue formal research project on leaf hair experiments. A full proposal will be re-submitted to SARE to establish a framework for a sustainable organic cotton seed production system. A manuscript will be submitted to Journal of Plant Registrations describing new okra-leaf cultivars CA 4014 and CA 4015. **\*\*Impacts\*\*** What was accomplished under these goals? From repeated season multi-location data and adventitious presence of GE traits, two candidate cultivars were selected to present to the Texas A & M Plant Release Committee and prepare for registration manuscript publication in Journal of Plant Registrations. Eight normal leaf and eight okra leaf cultivars were planted in replicated trials at two locations for the third year, since one location was not a repeat of the first year; data were analyzed and presented at the Beltwide Cotton Conference virtually (with first place graduate student presentation for Bradley Wilson). Seed increases were harvested, and three trial locations planted with next generation of okra-leaf lines. A SARE proposal was submitted to supplement farmer training on GE avoidance, "Establishing a framework for a sustainable organic cotton seed production system in west Texas." This proposal describes strategies and mechanisms to move cultivars developed in this project into commercial use. Texas A&M University Soil and Crop Science Department course SCSC 489, Organic Crop Production was taught in Fall semester by Co-PD Steve Hague. Organic farmers on our advisory board guest-taught some sessions. **\*\*Publications\*\*** - Type: Journal Articles Status: Published Year Published: 2020 Citation: Ayele, A. G., T. A. Wheeler, and J. K. Dever. 2020. Impacts of Verticillium wilt on photosynthesis rate, lint production, and fiber quality of greenhouse-grown cotton, *Gossypium hirsutum*. *Plants*. 9(7):857. <https://doi.org/10.3390/plants9070857> - Type: Journal Articles Status: Published Year Published: 2020 Citation: Ayele, A. G., J. K. Dever, C. M. Kelly, M. Sheehan, V. Morgan, and P. Payton. 2020. Responses of upland cotton (*Gossypium hirsutum* L.) lines to irrigated and rainfed conditions of Texas High Plains." *Plants* 9(11): 1598. <https://doi.org/10.3390/plants9111598> - Type: Journal Articles Status: Published Year Published: 2021 Citation: Zheng, L., J. Wu, F. Bourland, B. T. Campbell, J. K. Dever, S. Hague, G. O. Myers, T. B. Raper, C. W. Smith, and J. Zhang. 2021. Comparative study of transgenic and non-transgenic cotton. *Crop Science*. 61(4):2467-2477. <https://doi.org/10.1002/csc2.20522> - Type: Other Status: Published Year Published: 2021 Citation: Dever, J. K.,

V. Morgan, C. M. Kelly, A. Maeda, T. A. Wheeler, and K. Stair. 2021. Cotton performance tests in the Texas High Plains, 2020. Texas A&M AgriLife Research Technical Report 21-1. - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Wilson, B.W., S.A. Byrd, J.K. Dever, and C.M. Kelly. 2020. Impacts of leaf and bract pubescence on fiber quality of normal and okra leaf cotton. Proceedings of the Beltwide Cotton Conferences, p. 247-249, Austin, TX, January 8-10, 2020. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Wilson, B., S.A. Byrd, J. Dever, C.M. Kelly, and S. Hague. 2021. Effects of leaf and bract pubescence on fiber quality of normal and okra leaf cotton. Proceedings of the Beltwide Cotton Conferences, p. 229, Virtual, January 5-7, 2021. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Kelly, C. M., J. K. Dever, and V. A. Morgan. 2021 Registration of CA 4009 and CA 4010 cotton germplasm lines. Journal of Plant Registrations. 15(2): 366-371. <https://doi.org/10.1002/plr2.20126>

## PROGRESS

2018/09 TO 2019/08 Target Audience:Public cotton breeders and cotton research scientists involved in enhancing genetic diversity; companies involved in non-GM cotton seed breeding and development; organic cotton producers on the Southern High Plains. Commodity partners include Plains Cotton Growers, Cotton Incorporated, Cotton Foundation, and Texas Organic Cotton Marketing Cooperative.Public cotton breeders and cotton research scientists involved in enhancing genetic diversity; companies involved in non-GM cotton seed breeding and development; organic cotton producers on the Southern High Plains. Commodity partners include Plains Cotton Growers, Cotton Incorporated, Cotton Foundation, and Texas Organic Cotton Marketing Cooperative. Changes/Problems:Proliferation of low percentage GE adventitious presence (AP) persists even in okra-leaf nurseries and reduces the numbers of lines that can be tested on organic farms. Proposal by Global Organic Textile Standards to test seed cotton after harvest and before ginning for AP belies the National Organic Standards Board planting seed rules this project aims to address. What opportunities for training and professional development has the project provided?Graduate student Martin Costa participated in GE mitigation training with organic cotton farmers and seed producers in October. Project director Jane Dever attended Organic and Non-GMO Forum in October and presented a session on organic cotton at the AEIC Advancing Bioanalytical Technologies meeting in April. How have the results been disseminated to communities of interest?First and second year nursery results were reported at the annual meetings of the Plains Cotton Improvement Program board and Texas Organic Cotton Marketing Cooperative and biannually to the project advisory board. New course syllabus SCSC 489 is published in the Texas A&M University undergraduate catalog. What do you plan to do during the next reporting period to accomplish the goals?All nurseries, tests and leaf hair experiments will be harvested and analyzed; lines most appropriate for organic cotton production will be entered in multi-location performance testing on certified organic farms. Large-plot increases will be established to produce enough fiber for spinning trials. Two undergraduate students will complete internships and two graduate students, one at Texas A&M and one at Oklahoma State will continue formal research projects. A field day for organic cotton farmers will be held in the Fall to observe candidate cultivars under rainfed and irrigated organic production.

2020/09 TO 2021/08 Target Audience:Organic cotton growers (3) and ginners (1) were engaged regarding candidate cultivar releases and options to assist with selecting lines to go forward for seed production. Public cotton breeders and cotton research scientists involved in enhancing genetic diversity; companies involved in non-GM cotton seed breeding and development; organic cotton producers on the Southern High Plains. Partners with interaction during reporting period include Plains Cotton Growers, Cotton Incorporated, Organic Cotton Accelerator, Textile Exchange, Global Organic Textile Standards, Americot, Brownfield Seed and Delinting, and Texas Organic Cotton Marketing Cooperative. Texas A&M hired an Extension Organic Production Specialist, Bob Whitney, in June 2020. We have established contact and he is organizing extension and information session in which we will participate. Changes/Problems:A planned candidate cultivar demonstration with GPS coordinates for farmers to view at their convenience (in absence of group field days) with QR codes to multi-year, multi-location data was destroyed by tornado and hail damage. Seed increase blocks in another location were also damaged but still stand though quantities may be limited. Fiber will also be too limited to perform spinning trials, so advancement to commercial stage will be based on fiber properties only. Publication of cultivar registration manuscript is delayed. Another graduate student, Joshua Johnson, is being supported by the project after Martin Costa's early departure. Thus, a one-year extension of this project was requested and approved. What opportunities for training and professional development has the project provided?Graduate student Bradley Wilson virtually attended and presented project results at the Beltwide Cotton Research Conference in January 2021 and won first place in the graduate student competition. How have the results been disseminated to communities of interest?Nursery and test results were reported at the annual meetings of the Plains Cotton Improvement Program board and Texas Organic Cotton Marketing Cooperative and biannually to the project advisory board. Data for candidate organic cotton cultivars was provided to potential seed company partners.

Course syllabus SCSC 489 is published in the Texas A&M University undergraduate catalog. What do you plan to do during the next reporting period to accomplish the goals? Candidate cultivars planted in demonstration plots for organic farmer input was lost to tornados and hail damage, so it will be repeated in 2022. If 2021 seed increase is productive, lines most appropriate for organic cotton production will be available for demonstration plots on certified organic farms and breeder seed increase for transferring to planting seed production partners. Graduate student Bradley Wilson, Oklahoma State, will continue formal research project on leaf hair experiments. A full proposal will be re-submitted to SARE to establish a framework for a sustainable organic cotton seed production system. A manuscript will be submitted to Journal of Plant Registrations describing new okra-leaf cultivars CA 4014 and CA 4015.

## IMPACT

2018/09 TO 2019/08 What was accomplished under these goals? A pure okra-leaf breeding nursery is established; 24 of 39 individual plant selections were advanced to F5 progeny rows; and 49 of 83 were advanced to F4 progeny rows based on superior fiber quality, boll type appropriate for organic production, and resistance to bacterial blight. Five lines were selected from 120 progeny rows are planted in three irrigated and two rainfed multi-location performance testing. Three lines were selected for second year of testing on organic farms. Candidate cultivar 17-5-104 performed well under rain-fed production and 17-5-117 performed well under irrigated production. Eight normal leaf and eight okra leaf cultivars were planted in replicated trials at two locations; leaf hair ratings indicate appropriate variation to determine interaction of leaf hair and leaf shape on lint trash. First training for GE mitigation by visual screening was held October 2, 2018. Analysis of mechanical cottonseed delinting was completed in May. Texas A&M University Soil and Crop Science Department course SCSC 489, Organic Crop Production was taught in Fall semester by Organic farmers on our advisory board, Jimmy Wedel and Carl Pepper, guest-taught classes. \*\*PUBLICATIONS (not previously reported):\*\* 2018/09 TO 2019/08 1. Type: Journal Articles Status: Published Year Published: 2019 Citation: Kelly, C. M., J. Osorio-Marin, N. Kothari, S. Hague, and J. K. Dever. 2019. Genetic improvement in cotton fiber elongation can impact yarn quality. *Industrial Crops and Products* 129:1-9. 2. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Ayele, A., T. A. Wheeler, and J. K. Dever. 2019. Impact of Verticillium wilt on fiber quality of greenhouse-grown cotton (*Gossypium hirsutum* L.) breeding lines. Beltwide Cotton Research Conference. National Cotton Council of America. 3. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Wheeler, T. A., and J. K. Dever. 2019. Effect of Verticillium wilt and bacterial blight on commercial cotton varieties in 2018. Beltwide Cotton Research Conference. National Cotton Council of America. 4. Type: Other Status: Published Year Published: 2019 Citation: Dever, J. K., V. Morgan, C. M. Kelly, T. A. Wheeler, S. Vyavhare, K. Stair, and J. Arce. 2019. Cotton performance tests in the Texas High Plains, 2018. Texas A&M AgriLife Research Technical Report 19-1. 5. Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Arce, J., J. K. Dever, T. A. Wheeler, G. A. Holt, and S. Hague. 2019. Evaluation of mechanical cotton seed delinter for breeders. Beltwide Cotton Research Conference. National Cotton Council of America. PROGRESS: 2019/09 TO 2020/08 Target Audience: Public cotton breeders and cotton research scientists involved in enhancing genetic diversity; companies involved in non-GM cotton seed breeding and development; organic cotton producers on the Southern High Plains. Partners with interaction during reporting period include Plains Cotton Growers, Cotton Incorporated, Organic Cotton Accelerator, Textile Exchange, New Deal Grain, Inc., Brownfield Seed and Delinting, and Texas Organic Cotton Marketing Cooperative. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Graduate students Martin Costa and Bradley Wilson attended and presented project results at the Beltwide Cotton Research Conference in January 2020. Martin Costa completed non-thesis M. S. in May. Project director Jane Dever edited a situational analysis of organic cotton seed systems and intervention proposals per geography for the Organic Cotton Accelerator Global Organic Cottonseed Task Force. How have the results been disseminated to communities of interest? Third year nursery and test results were reported at the annual meetings of the Plains Cotton Improvement Program board and Texas Organic Cotton Marketing Cooperative and biannually to the project advisory board. Data for candidate organic cotton cultivars was provided to potential seed company partners. Course syllabus SCSC 489 is published in the Texas A&M University undergraduate catalog. What do you plan to do during the next reporting period to accomplish the goals? Final year of multi-location performance trials on 10 candidate cultivars will be completed. Lines most appropriate for organic cotton production will be available for demonstration plots on certified organic farms and breeder seed increase for transferring to planting seed production partners. Extensive testing for adventitious presence of GE traits will identify lines that can be transferred to breeder seed production. Large-plot increases will be established to produce enough fiber for spinning trials. One graduate student, Bradley Wilson at Oklahoma State, will continue formal research projects on leaf hair experiments. If invited, a full proposal will be developed

for SARE to establish a framework for a sustainable organic cotton seed production system. A field day for organic cotton farmers will be held in the Fall to observe candidate cultivars under rainfed and irrigated organic production. IMPACT: 2019/09 TO 2020/08 What was accomplished under these goals? The project moved from nursery to line testing and candidate cultivar stage after 2019. Repeated season multi-location data were prepared for 10 candidate okra-leaf cultivars. Candidate cultivars were tested for adventitious presence of GE traits. Eight normal leaf and eight okra leaf cultivars were planted in replicated trials at two locations for the second year; first year data were analyzed. Seed increases to plant 2020 spinning trial projects were harvested. A pre-proposal to SARE was submitted to supplement farmer training on GE avoidance, 'Establishing a framework for a sustainable organic cotton seed production system in west Texas.' This proposal describes strategies and mechanisms to move cultivars developed in this project into commercial use. Texas A&M University Soil and Crop Science Department course SCSC 489, Organic Crop Production was taught in Fall semester by Co-PD Steve Hague. Organic farmers on our advisory board guest-taught some sessions. PUBLICATIONS (not previously reported): 2019/09 TO 2020/08 1\ Type: Other Status: Published Year Published: 2020 Citation: Dever, J. K., V. Morgan, C. M. Kelly, T. A. Wheeler, and K. Stair. 2020. Cotton performance tests in the Texas High Plains, 2019. Texas A&M AgriLife Research Technical Report 20-1. 2\ Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Costa, M., J. K. Dever, and S. Hague. 2020. Breeding cotton for organic production. Beltwide Cotton Research Conference. National Cotton Council of America. 3\ Type: Theses/Dissertations Status: Published Year Published: 2019 Citation: Arce, Joel. 2019. Evaluation of a mechanical cottonseed delinter for breeders. Texas A&M University. 4\ Type: Journal Articles Status: Published Year Published: 2019 Citation: Zeng, L., D. L. Boykin, J. Zhang, E. Bechere, J. K. Dever, B. T. Campbell, T. B. Raper, S. Hague, C. Meeks, C. W. Smith, G. O. Myers and F. M. Bourland. 2019. Analysis of testing locations in regional high-quality tests for cotton fiber quality traits. The Journal of Cotton Science. 23:284-291. 5\ Type: Journal Articles Status: Published Year Published: 2020 Citation: Mathangadeera, R. W., E. F. Hequet, B. Kelly, J. K. Dever, and C. M. Kelly. 2020. Importance of cotton fiber elongation in fiber processing. Industrial Crops and Products. <https://doi.org/10.1016/j.indcrop.2020.112217>. 147 (2020): 112217. 6\ Type: Journal Articles Status: Published Year Published: 2020 Citation: Dever, J. K., C. M. Kelly, A. Ayele, J. Zwonitzer, P. Payton, and D. Jones. 2020. Registration of CA 4007 cotton germplasm line for water-limited production. Journal of Plant Registrations. 14(1):49-56. 7\ Type: Journal Articles Status: Published Year Published: 2019 Citation: Mauget, S., M. Ulloa, and J. K. Dever. 2019. Planting date effects on cotton lint yield and fiber quality in the U. S. southern high plains. Agriculture: 9(4) 82; doi:10.3390/agriculture9040082.

2020/09 TO 2021/08 What was accomplished under these goals? From repeated season multi-location data and adventitious presence of GE traits, two candidate cultivars were selected to present to the Texas A&M Plant Release Committee and prepare for registration manuscript publication in Journal of Plant Registrations. Eight normal leaf and eight okra leaf cultivars were planted in replicated trials at two locations for the third year, since one location was not a repeat of the first year; data were analyzed and presented at the Beltwide Cotton Conference virtually (with first place graduate student presentation for Bradley Wilson). Seed increases were harvested, and three trial locations planted with next generation of okra-leaf lines. A SARE proposal was submitted to supplement farmer training on GE avoidance, 'Establishing a framework for a sustainable organic cotton seed production system in west Texas.' This proposal describes strategies and mechanisms to move cultivars developed in this project into commercial use. Texas A&M University Soil and Crop Science Department course SCSC 489, Organic Crop Production was taught in Fall semester by Co-PD Steve Hague. Organic farmers on our advisory board guest-taught some sessions. \*\*PUBLICATIONS (not previously reported):\*\* 2020/09 TO 2021/08 1. Type: Journal Articles Status: Published Year Published: 2020 Citation: Ayele, A. G., T. A. Wheeler, and J. K. Dever. 2020. Impacts of Verticillium wilt on photosynthesis rate, lint production, and fiber quality of greenhouse-grown cotton, *Gossypium hirsutum*. Plants. 9(7):857. <https://doi.org/10.3390/plants9070857> 2. Type: Journal Articles Status: Published Year Published: 2020 Citation: Ayele, A. G., J. K. Dever, C. M. Kelly, M. Sheehan, V. Morgan, and P. Payton. 2020. Responses of upland cotton (*Gossypium hirsutum* L.) lines to irrigated and rainfed conditions of Texas High Plains." Plants 9(11): 1598. <https://doi.org/10.3390/plants9111598> 3. Type: Journal Articles Status: Published Year Published: 2021 Citation: Zheng, L., J. Wu, F. Bourland, B. T. Campbell, J. K. Dever, S. Hague, G. O. Myers, T. B. Raper, C. W. Smith, and J. Zhang. 2021. Comparative study of transgenic and non-transgenic cotton. Crop Science. 61(4):2467-2477. <https://doi.org/10.1002/csc2.20522> 4. Type: Other Status: Published Year Published: 2021 Citation: Dever, J. K., V. Morgan, C. M. Kelly, A. Maeda, T. A. Wheeler, and K. Stair. 2021. Cotton performance tests in the Texas High Plains, 2020. Texas A&M AgriLife Research Technical Report 21-1. 5. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Wilson, B.W., S.A. Byrd, J.K. Dever, and C.M. Kelly. 2020. Impacts of leaf and bract pubescence on fiber quality of normal and okra leaf cotton. Proceedings of the Beltwide Cotton Conferences, p. 247-249, Austin, TX, January 8-10, 2020. 6. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Wilson, B., S.A. Byrd, J. Dever, C.M. Kelly, and

S. Hague. 2021. Effects of leaf and bract pubescence on fiber quality of normal and okra leaf cotton. Proceedings of the Beltwide Cotton Conferences, p. 229, Virtual, January 5-7, 2021. 7. Type: Journal Articles Status: Published Year Published: 2021 Citation: Kelly, C. M., J. K. Dever, and V. A. Morgan. 2021 Registration of CA 4009 and CA 4010 cotton germplasm lines. Journal of Plant Registrations. 15(2): 366-371. <https://doi.org/10.1002/plr2.20126> \*\* \*\*

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# Economic and Environmental Sustainability of Heifer Development Strategies in Pasture-based Organic Dairy Systems

<b>Accession No.</b>	1013237
<b>Project No.</b>	UTA-01375
<b>Agency</b>	NIFA UTA\
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26866
<b>Proposal No.</b>	2017-02445
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2020
<b>Grant Amount</b>	\$999,404
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Isom, S. C.; Miller, RH, L.; Young, AL, J.; Peel, MI, .; Waldron, BL, .; Creech, J., EA.; Rood, KE, .; Feuz, DI, M.; Heleba, DE, .; Thornton-Kurth, KA, JE.

## NON-TECHNICAL SUMMARY

Dairy products constitute the second largest sector of the organic agriculture industry in the US. And dairy cow replacement costs are second only to feed costs in magnitude for the average dairy farm: between one-third and one-fourth of the entire herd is replaced every year. In order to maximize herd lifetime productivity (and thus sustainability), dairy heifers should be raised to approximately 60% of their mature body weight and bred by 15 months, in order to calve by their second birthday. This management challenge is not a simple one, even in conventional confinement-feeding programs. Given the National Organic Program requirement that ruminant animals be managed on pasture and graze daily throughout the grazing season, heifer development within organic systems is even more challenging, and more costly than in confinement systems. The primary objective of the current proposal is to innovate new strategies for organic forage-based dairy heifer development, and then to inspire widespread adoption of these practices for enhanced farm sustainability. The central hypothesis for the research arm of the proposal is that high energy grasses in combination with a high protein condensed tannin-containing legume will maximize growth, health, and reproductive characteristics in developing organic dairy heifers, along with improved nutrient cycling and economic sustainability. Ours is a truly "integrated" project, incorporating research, outreach, and educational components of crop science, animal science, environmental science and economics in order to make organic dairy heifer development a sustainable practice in every sense of the word.

## OBJECTIVES

The long-term goal of this research and outreach team is to enhance the economic, environmental, and social sustainability of pasture-based dairy farms nation-wide, but especially in the Intermountain West. Our primary objective is to develop an exclusively forage-based, organic system for dairy heifer development, and then to inspire widespread adoption of these practices for enhanced farm sustainability. The central hypothesis for the research arm of the proposal is that high energy grasses in combination with a high protein condensed tannin-containing legume will provide adequate nutrition to support proper growth, health, and reproductive characteristics in developing organic dairy heifers, along with improved nutrient cycling and economic sustainability. The following specific aims will allow us to accomplish our primary objective: Aim 1: Determine relative forage production potential and dairy cattle dry matter intake (DMI) in response to grazing grass-legume mixtures containing various tannin, protein, and energy levels. Aim 2: Assess dairy heifer health, growth, and

reproductive performance in response to grazing grass-legume mixtures containing various protein, energy, and tannin levels. Aim 3: Evaluate pasture-based dairy impact on nitrogen cycling in response to grazing grass-legume mixtures containing various protein, energy, and tannin levels. Aim 4: Conduct a comprehensive assessment of the economic sustainability of the various forage-based heifer development programs proposed herein. Aim 5: Implement an innovative and impactful multi-faceted extension/outreach program on the production and environmental benefits of grass/legume grazing for organic dairy production systems. This program will integrate traditional outreach efforts with electronic media, and will be guided throughout by input from our farmer/rancher team members and similar stakeholders. Emphasis will be placed on providing opportunities and resources to train these individuals in the local area, statewide, and across the western region.

## APPROACH

Three nine-acre experimental pasture plots were established at the Intermountain Irrigated Pasture Project (IIPP) facilities in Lewiston, UT in June 2015. The pastures were arranged in a randomized complete block design to accommodate three technical replications of each of eight experimental pasture 'treatments' (1.1 acres each). The eight pasture treatments consist of tall fescue, meadow bromegrass, high-sugar orchardgrass, and high-sugar perennial ryegrass in monocultures and binary mixtures with birdsfoot trefoil (BFT). Pastures will be irrigated weekly (1.5 inches) and grass monocultures will annually receive 75 lb N fertilizer from an approved organic source. Grass-BFT mixtures will not receive N fertilizer. For each of the two full grazing seasons that will make up this study, organically sourced post-pubertal Jersey dairy heifers (450±50 lbs; previously verified by ultrasound to be reproductively cycling) will be allocated to each of the eight pasture treatments (pasture n=72/year \* 2 years = 144 total pasture heifers/8 pasture treatments = 18 heifers/treatment over the two years) or fed a non-organically sourced total mixed ration (TMR) in confinement, as a control group (control n=9/year \* 2 years = 18 TMR heifers over two years). Pasture stocking rates will be three heifers per pasture (2.7 heifers ? acre-1). Rotational stocking will be used by moving heifers to a new paddock every 48 hours (17 paddocks approximately 0.03 acres each), resulting in a 34-day rotation cycle. Following grazing, paddocks will be mowed to a uniform height and harrowed to distribute manure piles as needed. Grazing will begin May 15 each year, and continue for 102 days (three 34-day rotation cycles), ending in late August. The TMR treatment will consist of three pen replicates of three heifers. Various observations, collections, and/or analyses will be made from animal, plant, soil, and water sources throughout the course of the year, as described below for each individual aim.

**Aim 1:** We will determine relative forage production potential and dairy cattle dry matter intake (DMI) in response to grazing grass-legume mixtures containing various tannin, protein, and energy levels. We will evaluate intake levels, nutrient content (DMI basis), and heifer performance (growth) using standard industry practices. Multivariate statistical analyses will determine which forage characteristics (e.g., protein, energy, etc) primarily contribute to differences in heifer DMI and performance.

**Aim 2:** We will assess dairy heifer performance in response to grazing grass-legume mixtures containing various protein, energy, and tannin levels. Specifically, we will measure growth by taking gross anatomical measurements (body weight, hip height, body condition score, etc) as well as systemic markers of growth (concentrations of Growth Hormone, IGF-1, Leptin in circulating blood, e.g.). We will evaluate markers of animal health, including parasite load and micronutrient content using fecal grab (Wisconsin sugar float) and liver biopsy (ICP-MS) samples, respectively. The effects of different forage treatments on heifer reproduction will be assessed by evaluating ovulation rates, first-service conception rates and reproductive hormone levels.

**Aim 3:** The impact of pasture-based dairy on nitrogen cycling in response to grazing grass-legume mixtures containing various protein, energy, and tannin levels will be determined. Nitrogen in the various phases (plant material, soil, leachate, fecal and urine samples) will be monitored and compared. A mass balance approach comparing total nitrogen outputs against total nitrogen inputs for each treatment will be utilized. In addition, roots will be sampled from each treatment to determine the importance of root structure on nitrogen capture and nutrient cycling.

**Aim 4:** We will undertake a comprehensive assessment of the economic sustainability of heifer development using the various forage-based programs being tested herein. Partial budgeting techniques will be used to determine the cost differences from each of the heifer development programs, and to quantify the impact of differences in the performance of the heifers under each system on the economic value of the dairy heifers. Ultimately, the partial budgets will be used to determine the most profitable method of raising the dairy heifers.

**Aim 5:** A centerpiece of this project will be a multi-faceted Extension program on the production and environmental benefits of grazing mixtures of high-energy grasses and tannin-containing birdsfoot trefoil, and how such mixtures can improve sustainability of organic, pasture-based dairy. This program will integrate traditional outreach efforts (on farm demonstrations, pasture walks, field days, and a regional pasture-based dairy conference) with electronic media (social media, webinar series, YouTube videos, e.g. all by eOrganic), and will be guided throughout by input from our farmer/rancher team members and similar stakeholders.

**\*\*FINAL REPORT\*\* 09/01/17 to 08/31/21 \*\*Outputs\*\*** Target Audience: The immediate audience for this work will be scientists and extension personnel working together to devise management practices to foster optimum forage-based grazing systems for heifer development. Changes/Problems: There were no major

problems that arose from our efforts. We were able to conduct the work essentially as outlined without significant deviations. What opportunities for training and professional development has the project provided? There were four graduate students that were trained exclusively on this study, and at least three more that played significant roles in data collection and analysis as well. The number of undergraduate students and other hired or volunteer help that participated in forage collections, animal handling, sample processing, and other data management and analysis is probably well over 30. The impact of these experiences for these students cannot be overstated. In addition, the pasture walks and field days that were held to engage producers and involve the community provided education and training for many others. How have the results been disseminated to communities of interest? Results from this project have been published in peer-reviewed scientific journals, extension fact sheets and popular press outlets. Additional publications are in various stages of preparation. There have been at least six presentations made at International/national scientific meetings, as well as many regional and local venues. At least three major extension/outreach events were held to share this work with local and regional producers and other interested community members. Four webinars were delivered as a part of the outreach effort and these four presentations have been viewed 2,050 times for an average of approximately 500 views per webinar. What do you plan to do during the next reporting period to accomplish the goals? We plan to pursue research that investigates the significance of animal genetics (breed) on measures associated with performance on pasture. Beyond growth and intake, we will consider factors such as genomic markers, parasite load, rumen microbiome composition, tannin sources and concentrations, organic-approved fertilizers, and pasture management systems, among others. But as this is the final report, no more specific plans are reported for this project. **\*\*Impacts\*\*** What was accomplished under these goals? The purpose of this study was to investigate the effects that different forages in a rotational grazing system have on the development of organically raised dairy heifers and to analyze the complimentary effect of high energy grasses with birdsfoot trefoil (BFT) tannins to improve intake of dairy heifers. Over 3 years, 210 yearling Jersey heifers were assigned to one of nine treatments, including a conventional dry lot control (TMR) or one of eight pasture treatments. Pasture treatments included: tall fescue (TF), meadow bromegrass (MB), orchard grass (OG), perennial ryegrass (PR) and each individual grass interseeded with birdsfoot trefoil (BFT). Intake was measured by sampling herbage before and after each seven-day rotational grazing period. Every 35 days, over a 105-d period, heifers were weighed, measured for hip height, and blood samples were collected to determine serum insulin-like growth factor-1 (IGF-1) and blood urea nitrogen (BUN) concentrations. Fecal samples were collected to determine fecal egg count (FEC). Speaking generally (but not absolutely), intakes were higher in heifers on BFT-containing pastures. Intakes amounts from greatest to least were as follows: MB+BFT, OG+BFT, OG, MB, PR+BFT, TF+BFT, PR, TF. Physical characteristics of herbage samples such as pasture bulk density, herbage height, herbage allowance, leaf pubescence, leaf softness, and birdsfoot trefoil content as well as nutritional properties such as fat, non-fibrous carbohydrates, fiber, and energy were all associated with intake. Crude protein and ash were also associated with intake. While PR+BFT did not have the greatest overall intake, it was the only treatment that consistently had greater intake than its respective grass monoculture (PR). Since it had more energy and tannins than all other grasses, a complimentary effect between energy and tannins to increase intake was likely. The fact that both physical and chemical herbage characteristics were associated with intake shows the importance of planting the right species in pasture as well as making proper management decisions to maximize nutritive value and herbage intake. Regarding animal performance on different pasture types, heifer body weights (BW), BUN, and IGF-1 concentrations were affected by treatment ( $p < 0.01$ ) when analyzed over time. Heifers on mixed legume-grass pastures (MIX) tended to have greater BW compared to heifers on monoculture grass pastures. Heifers receiving TMR or PR+BFT had increased BW gain ( $p < 0.05$ ) over the 105-d period than heifers grazing TF+BFT, OG, PR, MB, or TF. Whereas, at d 105, heifers receiving TMR, PR+BFT, OG+BFT, or MB+BFT had greater ( $p < 0.05$ ) BW than heifers receiving TF. Heifer hip-height, conception rate, and FEC were not affected ( $p > 0.05$ ) by pasture type when analyzed over time. Heifers grazing MIX pastures had greater ( $p < 0.01$ ) BUN compared to heifers grazing MONO pastures. Herbage intake by heifers in our study was largely influenced by both physical and nutritive herbage characteristics noted above. The most important nutritive characteristics included energy and fiber related traits such as fat, NFC, NDF and ADF, metabolizable energy and net energy gain. Crude protein and ash were also associated with intake. While we hypothesized that birdsfoot tannins would interact with grass energy to increase intake, they did not come up as an important characteristic in the multivariate analysis, possibly due to the small amount that we observed in the herbage. However, the two treatments with the most BFT (PR+BFT and MB+BFT) generally showed an increase in intake over their respective monocultures while the other two mixtures did not. Furthermore, PR+BFT had the greatest concentration of energy and tannins compared to all other treatments, suggesting that a complimentary effect between energy and tannins occurred to increase herbage intake in this treatment. The results of this study show the importance of not only planting the right type and composition of grasses and legumes but using best management practices as well. Planting highly nutritious grasses and BFT in the right proportions (at least 20% BFT) and managing animals in a way that maintains moderately tall, dense herbage with favorable leaf texture characteristics must both be taken into account if managers are to optimize intake on pasture. These data provide a comparison between how grass pastures,

grass/legume mixed pastures, and a TMR affect the development of replacement dairy heifers. The results demonstrate that interseeding a legume, BFT, with pasture grasses increases heifer weight gain. Weight gains of heifers grazing mixed pastures were also similar to heifers who were fed a TMR. Results from the present study also indicate that heifers grazing BFT mixed pastures had higher BUN concentration than animals on grass pastures. Even with higher levels of BUN, animals grazing BFT mixed pastures never surpassed BUN concentrations that are known to be detrimental to reproduction. Our results also indicated that serum IGF-1 levels were commonly higher in heifers fed a TMR when compared to heifers grazing TF. Heifer parasite load, hip-height, and conception rates were not affected by the presence of BFT in pasture or any of the specific treatments. This research demonstrates that grazing heifers on grass-BFT mixed pastures may be a sustainable method to improve dairy heifer development in animals consuming pasture. \*\*Publications\*\* - Type: Journal Articles Status: Published Year Published: 2021 Citation: Hadfield, J., Waldron, B. L., Isom, S., Creech, J. E., Rose, M. F., Long, J., Miller, R. L., Rood, K. A., Young, A., Stott, R. D., Sweat, A., & Thornton-Kurth, K. (2021). The effects of grass and grass-legume pastures on organic dairy heifer development: Heifer growth and performance. *Journal of Dairy Science*, 104(10), 10863-10878. - Type: Conference Papers and Presentations Status: Other Year Published: 2021 Citation: Presentations Fannesbeck, S. (Presenter & Author), Thornton-Kurth, K. (Author Only), Waldron, B. (Author Only), Stott, R. D. (Author Only), Sweat, A. (Author Only), Rood, K. (Author Only), Creech, J. E. (Author Only), Young, A. (Author Only), Isom, S. (Author Only), American Society of Animal Science, "Influence of cattle breed and forage type on organic dairy heifer performance," Louisville, KY. (July 2021) - Type: Conference Papers and Presentations Status: Other Year Published: 2021 Citation: Presentations Fannesbeck, S. (Presenter & Author), Thornton, K. J. (Author Only), Waldron, B. (Author Only), Stott, D. (Author Only), Sweat, A. (Author Only), Rood, K. (Author Only), Creech, J. E. (Author Only), Young, A. (Author Only), Isom, S. C. (Author Only), Annual Meeting of the American Society for Animal Science, "Influence of cattle breed type and forage type on organic dairy heifer performance. American Society for Animal Science," American Society for Animal Science, Louisville, KY. (July 2021) \*\* \*\*

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# Organic Confluences Conference: Evaluating and Advancing Knowledge Transfer in Organic

<b>Accession No.</b>	1013166
<b>Project No.</b>	DC.W-2017-02425
<b>Agency</b>	NIFA DC.W\
<b>Project Type</b>	OTHER GRANTS
<b>Project Status</b>	NEW
<b>Contract / Grant No.</b>	2017-51300-26850
<b>Proposal No.</b>	2017-02425
<b>Start Date</b>	01 SEP 2017
<b>Term Date</b>	31 AUG 2018
<b>Grant Amount</b>	\$50,000
<b>Grant Year</b>	2017
<b>Investigator(s)</b>	Shade, J.; Greene, CA, RE.; Formiga, AL, .
<b>Performing Institution</b>	ORGANIC CENTER FOR EDUCATION AND PROMOTION, 28 VERNON ST STE 413, BRATTLEBORO, VERMONT 05301

## NON-TECHNICAL SUMMARY

The primary goal of this conference is to evaluate the efficacy of information delivery systems for organic producers and develop strategies to improve communication and facilitate knowledge transfer across the organic sector. Organic farming is fundamentally different from conventional farming and past research indicated that lack of information and unsupportive cooperative extension were major barriers to success for organic and transitioning farmers. Organic farming, however, is evolving at an extraordinary pace and the extent to which current information delivery systems support organic farmers is unclear. This conference will address the need for an updated evaluation of information systems for organic farmers through panels, case studies and discussions. Specifically, this conference will 1) Evaluate existing information services as they relate to organic and transitioning farmers; 2) Highlight innovative organic agriculture extension and education efforts; 3) Develop strategies for increasing communication among researchers, extension, industry and farmers and 4) Build recommendations that can be used to develop a framework for improving knowledge transfer, education and extension in the organic sector. Participants will include organic and transitioning farmers, extension agents, scientists, educators, industry members and key policy influencers. The conference will be held in Washington, D.C., on May 2-3, 2018, in conjunction with the Organic Trade Association's Policy Conference and Farmer's Advisory Council Summit, which are attended by organic farmers from small and large farms, distributors, researchers, organic brands, retailers and policymakers. Proceedings and a white paper from the conference will be made available through The Organic Center and published by eOrganic.

## OBJECTIVES

The primary goal of this conference is to address barriers to increasing adoption of organic practices and expanding organic acreage. In an effort to achieve this broader goal, we will bring together a diverse group of organic stakeholders to evaluate the efficacy of information delivery systems for organic producers and develop strategies to improve communication and facilitate knowledge transfer across the organic sector. Conference participants will include organic and transitioning farmers, extension agents, scientists, educators, industry members and key policy influencers. Organic farmers and especially those who are new or transitioning to organic rely on information and technical advice to maintain successful operations. In the past, lack of information was

one of the primary factors that led farmers to abandon organic farming, and farmers consistently cited information gaps as a significant barrier in the transition to organic farming. However, over the past decade, there has been little formal assessment of the ability of information services to meet the needs of organic and transitioning farmers. This conference will fill this knowledge gap by evaluating the current landscape of information transfer systems for organic farmers, expanding strategies for increasing communication among researchers, extension, industry and farmers, and building recommendations that can be used to develop a framework for improving knowledge transfer, education and extension in the organic sector.

## APPROACH

Conference programming will take a multifaceted approach to evaluating the efficacy of agricultural extension and education for organic and transitioning farmers and address barriers to effective information communication and utilization. Day One will focus on in-depth assessments of information delivery systems as they pertain to specific sectors of the organic farming community. Case study areas will be determined by our Advisory Committee (Appendix C). Example case studies include information transfer in the organic grain sector, organic dairy sector, diversified vegetable sector or information systems focused toward new and transitioning farmers. Stakeholders will assess the infrastructure in place for extension and education in each of these areas and the degree to which the information or recommendations are being utilized or adopted. Day Two will draw on conclusions from the case studies, and will expand the discussion to include panels and roundtable discussions to assess (1) the types of communication that are most impactful to farmers, (2) highlight innovative extension and education services, (3) information needs of new and transitioning organic farmers, (4) efficacy of existing information sources, and (5) the effectiveness of current organic agriculture research funding requirements for the inclusion of extension and education activities with a focus on the results from Organic Farming and Research Foundation's "Taking Stock: Analyzing and Reporting Organic Research Investments 2002 - 2014". The conference will culminate with discussions to synthesize information presented at the conference and to develop strategies for increasing communication among researchers, extension, industry and farmers and build recommendations that can be used to develop a framework for improving knowledge transfer, education and extension in the organic sector. The conference will employ a Core Planning Team (Appendix C) to take on the administrative tasks of conference planning. The Core Planning Team will be responsible for organizing the program. It will lead session planning, facilitator recruitment, development of special topics, identification of keynote speakers, and development of guidelines for soliciting submissions and presentation approval. The Core Planning Team will meet via conference call on a regular basis and will seek input from the General Advisory Committee throughout the planning process. The General Advisory Committee will also help identify potential speakers, review paper submissions and disseminate outreach materials. The Organic Center will be responsible for all logistical arrangements including organizing meetings, coordinating with participants and stakeholders, creating print material, writing and disseminating press releases and social media outreach and acting as the main contact for any inquiries regarding the conference. The conference will be held at the USDA Conference Facility at Patriots Plaza III in Washington, D.C. **\*\*FINAL REPORT\*\* 09/01/17 to 08/31/19 **\*\*Outputs\*\***** Target Audience: The target audiences reached by the Organic Confluences Conference include scientific experts, farmers, policymakers, industry and extension agents. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest? The report has been disseminated and publicized via the eOrganic website and newsletter, the Organic Center's website and newsletter and the Organic Trade Association's website and newsletter. The report was shared with all conference participants and was shared via email with almost 8,000 U.S. certified organic farmers. The report was also shared with program leaders at USDA-NIFA. Additional outreach and dissemination was targeted at land grant universities with organic and sustainable agriculture programs. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **\*\*Impacts\*\*** What was accomplished under these goals? During this reporting period The Organic Center wrote, published and disseminated a white paper developed from the conference entitled "Evaluating and Advancing Knowledge Transfer in Organic: Outcomes from the 2018 Organic Confluences Conference". It covers panel discussions that (1) examined the past, present and potential future of the Cooperative Extension system as it pertains to organic farming; (2) discussed the role of public-private partnerships in augmenting organic agriculture extension and education; (3) highlighted the importance of effectively communicating to a wide range of diverse organic agricultural stakeholders; (4) assessed the effectiveness of extension requirements in organic agriculture research funding, and (5) considered tactics for reaching farmers considering transitioning to organic production. It also covers lightning session presentations that allowed presenters five minutes each to highlight existing examples of inventive information transfer. The session covered innovative programs, organizations, and companies pioneering new ways to connect farmers with useful information. Finally, it covered outcomes from small group discussions allowing participants to ask questions targeted at tackling the challenges addressed during the conference and developing recommendations for improving the outlook for organic crop production. In

summary, the report detailed the need for: Additional training about organic practices for extension agents across the nation. Educational material and events that are inclusive to farmers from a diversity of backgrounds, and involvement of underrepresented communities in trainer leadership. Ensuring that extension requirements in granting guidelines encourage effective results communication and require farmer engagement from the naissance of the project idea through to the implementation of the findings. Additional public-private partnerships that allow increased focus and funding for organic extension. Additional research, development, and communication of regional knowledge, networks, and tools. Developing a network of cooperation between extension agents, industry members, educational non-profits, and other non-traditional forms of information transfer to organic farmers. An aggregated repository of organic educational materials that is curated for credibility and usability. Additional organic train-the-trainer materials and events. The report has been disseminated and publicized via the eOrganic website and newsletter, the Organic Center's website and newsletter and the Organic Trade Association's website and newsletter. The report was shared with all conference participants and was shared via email with almost 8,000 U.S. certified organic farmers. The report was also shared with project leaders at USDA-NIFA. Additional outreach and dissemination was targeted at land grant universities with organic and sustainable agriculture programs. \*\*Publications\*\* \*\*ORG Awards\*\*

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