OREI Project Details

Award Year 2020

20 Research Projects

PROJECT INDEX

Scope 2.0: Refining Organic Breeding Pipelines to Produce Improved Varieties and Workforce

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NON-TECHNICAL SUMMARY

Organic farming systems are distinct from conventional farming systems. Consequently, plant breeding activities focused in organic farming systems will result in cultivars well tailored to production needs of those systems, such as improved disease resistance or novel traits. Further, a range of niche consumer markets exists for organic producers, including new and novel traits or trait combinations. The objectives of this program are to breed new varieties of common bean, pepper, tomato, wheat, and zinnia for organic producers in California and neighboring states. This project builds on our OREI-funded, existing successful breeding pipelines that are led by students who gain experiential training in field-based plant breeding directly in organic systems, both at the UC-Davis and Cal Poly Pomona organic student farms and on-farm with organic producers. With both self- and cross-fertilized crops and vegetable, agronomic, and ornamental species, students will gain familiarity with a broad complement of breeding systems and variety types, including open-pollinated and hybrid cultivars and develop new cultivars to meet the needs of diverse organic growers. The Organic Seed Alliance will organize regular interactions and meetings between student researchers, faculty, organic seed companies, and organic growers. We will develop and conduct on-farm trials, host extension events at trial sites, and ensure that new, publicly released cultivars derived from our program will be useful and available to organic growers and organic seed companies.

OBJECTIVES

Long-term goals Our long-term goals are providing experiential plant breeding learning opportunities for graduate and undergraduate students who will become the plant breeding leaders of tomorrow while producing and ultimately releasing cultivars useful to the organic grower and seed producer communities. The specific objectives of the Student Collaborative Organic Plant-Breeding and Education (SCOPE) 2.0 project are as follows: To develop and release cultivars of vegetables, grains, and flowers from our organic breeding pipelines with participation of the organic farming community,To educate and train the plant breeding leaders of tomorrow by empowering students to lead organic breeding programs, from concept through variety release, providing experiential learning opportunities in real world cultivar development,To extend our breeding outputs to the

organic farming, seed, and research communities through on-farm trialing of new experimental varieties, interactions with breeding companies, field days, and other activities.

APPROACH

Beans: Trials on grower farms will be conducted as either small plot replicated trials in order to test several different experimental lines against check cultivars or if seed is available, in larger strip trials planted and maintained using farm-scale equipment to get a better sense of production potential. Trials will be conducted using common practices for bean production, as we have been doing for the past five years of this project. We will continue to contact seed companies for trialing and potential marketing outlets.Peppers: Advanced breeding trials will be random complete block designs for replicated trials with a minimum of three replicates on at least three irrigated locations per year (all farms irrigate in California growing regions) using current widely grown varieties as checks. Each plot is represented by 12 transplants for replicated trials with border plants and rows to limit border effects. Data on stand count, vigor, days to breaker, sun-scald (on scale of 1-5 at harvest), fruit size and shape (photo and scale), taste, as well as yield is recorded. Taste is taken in the field by student breeders and through consumer and farmer surveys. Data are collected using the Field Book app (phenoapps.org/) for handheld devices and analyzed using R (R Core Team, 2018), both powerful tools for breeding that are freely available. For yield or other quantitative traits, means will be adjusted using best linear unbiased predictions (BLUPs). Analysis of variance and protected LSD are used for mean separation. Advanced selections are also tested for pungency with genetic markers using KASP assays in-house.Tomatoes: Augmented designs are used for early generation nurseries and alpha-lattice or RCBD for replicated trials. Nursery plots are with 6 plants and 12 plants for replicated trials. Data will be analyzed and collected as for pepper (see above). We will makes crosses with a NC II diallel design between heirloom lines and lines derived from commercial hybrids. Heirloom varieties have been shown to be diverse from commercial F1 hybrid fresh market varieties (Robbins et al., 2011). Parents with high general combining ability will be used to establish testers for male and female sides to establish a reciprocal recurrent selection program. Testcrosses will be evaluated in replicated trials beginning in Year 3 and extending beyond this the proposal, with selections advanced to produce the best hybrids for the above traits. Marker assisted selection will be used to identify parents to combine alleles for disease resistance as above.Wheat: The main breeding and evaluation trials will be conducted at the UC Davis Student Organic Farm using a plot planter or hand sown and harvested with a Wintersteiger Classic Plot Combine or by hand. Plot size will be 5m x 1.5m with a 0.5m mowed or tilled alleyway between plots. Plots consisting of advanced material or varieties for evaluation will be planted in three replications in a RCBD. On-farm trials will be set up as \'Hen and Chick\' trials, similar to the \'Mother and Baby\' trial design used in participatory plant breeding (Snapp, 2002). In this trial design on-farm \'chick\' trials will consist of farmer-chosen subsets of the comprehensive \'hen\' trials (UC Davis). These trials have been conducted in 2018 and 2019 in Yolo and Lake Counties. Spring-planted trials will be conducted on certified organic land the UC Intermountain Region and Extension Center (IREC) in Tulelake, CA near the Oregon border at an elevation of 4000 feet. IREC is part of the UC Division of Agriculture and Natural Resources (ANR), and supports both UC research in field and vegetable crops in the Klamath Basin. The environment here differs greatly from the Central Valley and small grains are spring-planted rather than fall-planted. This location will also be used as an off- season nursery to advance generations in the breeding program.Flour tests will be run using whole grain and bake tests will use a whole grain sourdough protocol co-developed by the CWC and artisanal bakers (Krill-Brown 2019). A subset of the best quality lines will be sent to professional bakers for evaluation of mixing, handling and baking properties. Informal sensory and taste tests will be done at various events and with a diversity of products. The main sensory testing for bread quality will involve CWC experts, bakers, food science interns from UCD, and SCOPE students. Although the focus will be on evaluating bread quality, we will also evaluate various other products (waffles, pasta, tortillas, etc.) based on interest from the students.Zinnia: Zinnias will be started in the greenhouse and transplanted into the organic Student Farm and managed following current practices (Fig. 5). Germplasm will be randomized and replicated within rows, using augmented designs or RCBD, depending on the number of entries. Because zinnia is outcrossed, plots will consist of 5-10 plants per entry in each replication. Flowers for crossing will be bagged or otherwise isolated to control pollination. Data to be collected includes flowering time (degree days from transplanting), flower color, petal shape, disease incidence, and others. Post harvest analysis of shelf-life, both with and without cold storage will be evaluated.Students: Experiential learners move through a cycle of concrete experience, reflective observation, abstract conceptualization and active experimentation (Kolb, 1984). Interns participating in this program will move through such a process, keeping journals to reflect on and apply their newly gained knowledge. Interns will participate in hands-on activities 2-3 hours per week and attend a one hour participatory seminar where they will hear from plant breeders, seed producers, organic farmers, and other stakeholders. Part of the seminar series during this year will be structured from fall quarter through spring quarter each year to provide an overall set of plant breeding concepts. The structured part of the series will be easily transferred to Cal Poly Pomona, and to other universities, as a web-based curriculum consisting of short videos

of breeding activities and slide sets explaining basic concepts. First and second quarter interns will keep weekly journals, third quarter interns will do a \"Field Learning Demonstration\" internship where they demonstrate and teach a management aspect of the breeding program to other interns. Fourth quarter interns will have the option to do a specialized internship where they take on responsibility for one aspect a crop\'s breeding program. Progress 09/01/20 to 08/31/24 Outputs Target Audience:The target audience of the SCOPE project is broad, ranging from undergraduate and graduate students and faculty at UC Davis and Cal Poly Pomona, to scientists at other universities and institutions, organic growers, organic seed producers and seed companies, and more broadly, the public. In the final year of the SCOPE 2.0 project, we hosted events and crafted outreach materials targeting these groups, with also included stakeholders associated with the Organic Seed Alliance\'s and California Wheat Commission\'s networks. In partnership with OSA, our events have been attended by a network of organic seed producers and seed companies, organic farmers, researchers, food company representatives, and other stakeholders. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?One of the goals of this project were to provide experiential plant breeding learning opportunities for graduate and undergraduate students who will become the plant breeding leaders of tomorrow while producing and ultimately releasing cultivars useful to the organic grower and seed producer communities. During this grant period, we refined an internship structure that engages students as lead plant breeders, including integrating the SCOPE internship program and field trials within the existing set of UC Davis Student Farm experiential internship programs to manage the program more smoothly within the Farm. In total, 22 graduate students, 38 undergraduates participated in the program at UC Davis and 3 graduate students and 9 undergraduate students participated in the tomato breeding program at Cal Poly Pomona. In addition, one graduate student and one undergraduate student participated in SCOPE at both Cal Poly Pomona and UC Davis. Two Cal Poly students also began working on the SCOPE tomato project as undergraduates and have since continued on the project as graduate students. During the grant period, each student participated for 2.3 academic quarters on average. In the same time period, SCOPE trained an additional five paid student assistants who stayed in SCOPE for an average of 4.8 academic quarters, or just over 1 calendar year. Five undergraduate students working with SCOPE in that time period went on to become graduate students at UC Davis after graduation. In addition to undergraduates, 22 graduate students and 2 post-docs worked with SCOPE at UC Davis between Fall 2020 and winter 2023. In 2021, the Student Farm and SCOPE implemented a post-internship evaluation form. Evaluation results demonstrated that SCOPE was instrumental in exposing plant breeding to many undergraduates and showing them how breeding related to their goals for sustainable food systems. It also showed that students appreciated the welcoming community formed in SCOPE and at the Student Farm, and that they found the experiential, hands-on components especially valuable to developing conceptual understanding of breeding concepts and understanding the practical and human aspects of plant breeding and agriculture more generally. COVID-19 restrictions on research prevented SCOPE from hosting undergraduate student assistants or interns on site from Sept. 2020 to June 2021. During that time, staff and graduate students developed an alternative, remote internship program where students engaged in at-home taste-tests and bake tests, published recipes using SCOPE crops, edited videos demonstrating how to make cross pollinations, and edited the recorded seminar videos from the remote internship program. The practice of recording and publishing the semi-weekly seminars continued after in-person instruction returned, and these videos are available on the SCOPE website (https://plantbreeding.sf.ucdavis.edu/scope-shareale-resources) We also coordinated a field trip of four SCOPE students to the 2023 California Spring Trials, an exhibition of new varieties released by ornamental and horticultural breeding companies in California. How have the results been disseminated to communities of interest?We hosted an annual field day at the UC Davis Student Farm where the bulk of the breeding work at SCOPE takes place in September 2023 and 2024, with 40-50 participants each year. We made presentations (either students, staff, or faculty) to various courses in the Plant Sciences major, including PLS2, PLS15, PLS152, PLS154, HRT200A, and others. We conductd participatory tomato taste tests at the SCOPE field day, at separate events held by the UC Davis Student Farm, and as part of Seed Central, a breeding and networking event for commercial plant breeders and university personnel held at UC Davis. We presented an overview of SCOPE activities at the annual Plant Breeding Retreat held each year at the Bodega Bay Marine Lab, which is part of UC Davis. This event included \~75 participants, most of whom did not know about the SCOPE project otherwise. We hosted several seed company personnel and other interested people for one-on-one visits throughout the year. We have an Instagram channel where we post activities of the project \@ucdscopeproject. 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. Common (Dry) Bean: SCOPE was able to release five cultivars of common bean in 2021, led by Travis Parker, the lead graduate student on the bean breeding team. After these releases the common bean project was terminated at UCD and new crops were added to the SCOPE portfolio. However, the on-farm and research trials used to gather data on these cultivars for release, identified additional germplasm that is well suited to coastal dry-farmed environments and may be useful if we bring back the common bean project at a later point. Pepper: Applications to release three pepper cultivars will be submitted to the UC Davis Plant Materials Release Committee. These peppers include two jalapeño type with larger cavities

designed for stuffing with cheese for use as \"poppers\" and one bell pepper with improved sunscald tolerance. Tomato: We have evaluated 63 cultivars as possible parents for the tomato program and 101 families (F3-F8) have been generated for inbred line development between UCD and CPP. In 2021, 22 inbred lines from SCOPE-UCD, SCOPE-CPP, and collaborating Organic Seed Alliance breeders were trialed at UCD and CPP. Six lines were selected based on performance and fruit shape, size, and color variation as parents for hybrid development. Nine F1 hybrids were trialed in 2022 and 13 additional F1 hybrids were trialed in 2023. Three F1 hybrids trialed in 2022 were as promising experimentals and were included in the 2023 replicated field trials at UCD and CPP to collect data for possible release. Seven advanced inbred lines have been identified for potential cultivar release and were evaluated in replicated field trials at UCD and CPP in 2023. After trials in 2024, 2 inbreds developed at UCD, and 3 inbreds developed at CPP were identified for potential variety release. Wheat: The organic wheat breeding program has focused on the evaluation of germplasm for adaptation to California organic production systems, especially for fall-planted spring wheat. The germplasm evaluated in organic systems has included elite (unreleased) and public cultivars from the UC Davis wheat breeding program (conducted on conventionally farmed land); older cultivars no longer under plant cultivar restrictions (xPVP); landrace/heirloom cultivars of interest to stakeholders and breeding material developed as part of SCOPE. Based on the information gained from trialing, several breeding populations were developed to combine unique traits such as color or flavor with superior performance under organic conditions (high grain quality, disease resistance, drought tolerance, yield stability, etc). In addition to field testing, we identified measurable quality parameters for the performance of organic whole grains and developed a rating scale for growers, millers and bakers to use to determine the optimal use for a wheat cultivar (e.g., bread, tortillas, crackers, cookies). Several taste tests were performed to identify wheat lines with optimal flavors and textures. As of the end of this grant period, about 40 advanced lines, and 3 off-patent varieties have been identified for further evaluation, including 14 blue lines and 8 \"charcoal\" (dark red-brown) lines. In addition, approximately 20 advanced lines developed by the conventional UC wheat breeding program have been tested under organic management each year, with 1 being identified for potential release as an organic-adapted variety. Zinnia: The zinnia project began in spring 2020. In summer 2020, we evaluated 40 germplasm accessions from which we selected plants used to make 195 biparental crosses. Our breeding program is focused on five primary traits: color, petal shape, flower size, stem length and disease resistance which are organized into four breeding groups targeting one or more traits. In 2021 and 2022, multiple full- and half-sib families for each group were evaluated in replicated trials, with individual plants in families phenotyped for color and other traits. Desirable plants were intercrossed in the field and/or greenhouse. In 2023, 11 promising populations from the target breeding groups were advanced while additional crosses continue to be made and evaluated. In 2023, the breeding program began producing bulk seed through the use of blue bottle fly pollinators in isolation cages, to produce enough seed for on-farm trials. Celtuce: We developed a new breeding project on celtuce, stem lettuce, during this grant. This project is a collaboration with Second Generation Seeds and several grower/breeders from the Asian-American community who are interested in expanding the growing season for celtuce among other things. We have made crosses at UC Davis and provided collaborating farmers with segregating populations for them to make selections. Additional crosses were made in 2024 and these plus advanced selections will be evaluated in 2024-2025 as the project continues on a new grant. Objective 2. See the next section in the report on \"Opportunities for training\". Objective 3. A subset of tomato lines were trialed with farms partnering with the Organic Seed Alliance. Additional outreach in the wheat program has included the stone milling and free distribution of leftover grain by SCOPE students. We have also contributed to the Wheat2Schools program led by Claudia Carter, executive director of the CWC, to educate K-12 students and promote the use of whole grains in diets by providing seed and educational material. Several schools are growing, selecting and saving wheat populations we distributed to them. Every year, we assist with the harvesting and processing of small wheat plots at Dingle Elementary School in Woodland, funded by the Yolo Farm to Fork Initiative. We developed relationships with several small seed companies that were interested in trialing our zinnias for potential inclusion in their catalogs. This included Floret, a flower farm and seed company based in Mt. Vernon, WA. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Roser, Laura, Antonia Palkovic, Allison Krill-Brown, Luis Salazar, William Hazzard, James Weeks, Saarah Kuzay, Katharina Ullmann, Colin Dixon, Priti Saxena, Jared Zystro, Jorge Dubcovsky, Allen Van Deynze, and E. Charles Brummer. 2024. SCOPE 2.0: Refining Organic Breeding Pipelines To Produce Improved Varieties And Workforce. USDA National Institute of Food and Agriculture 2024 Organic Agriculture Annual Project Director Meeting. April 24-25, 2024. Orlando, FL. Progress 09/01/22 to 08/31/23 Outputs Target Audience:In the third year of the SCOPE 2.0 project, we again hosted events and crafted outreach materials targeting our large network of students, faculty, plant breeders, seed producers, organic farmers, and other stakeholders tied to the Organic Seed Alliance\'s and California Wheat Commission\'s networks. Our undergraduate internship program built on previous quarters\' experiences to gain more independence and leadership roles, and increase undergraduate-faculty interaction. The student-led breeding projects created opportunities for graduate students across disciplines to participate in field management and breeding concepts, data collection, seed production, and fruit processing. The projects also increase student understanding of the practice and theory of plant

breeding, and strengthen the participatory network of stakeholders engaged in this project. In partnership with OSA, our events have been attended by a network of organic seed producers and seed companies, organic farmers, researchers, food company representatives, and other stakeholders. Each spring, OSA also helped coordinate outreach with partnering regional organic farms to coordinate variety trials. We also continue to highlight project outcomes through the SCOPE website (https://plantbreeding.ucdavis.edu/scope- project), and shared through partner websites, social media, and listserves. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The SCOPE breeding programs are managed by a network of students, faculty, and staff at UC Davis and Cal Poly Pomona, the UCD Plant Breeding Center, and farmers in the region. Our field-based breeding programs give students real-world experience breeding crops by getting them in the greenhouse and field to observe breeding germplasm and see how programs function. Graduate and undergraduate learn about experimental design, cross-pollinating, making selections, collecting phenotype data, data analysis, and more. We also expect students to further develop functional \"soft skills\" that are required in most workplaces, such as time management, confidence in leading groups, teaching skills to others, and critical thinking. How have the results been disseminated to communities of interest?Recording, editing, and publication of 27 videos from online seminars recorded with the SCOPE program during the COVID-19 pandemic. The videos cover topics such as the basic principles of plant breeding, domestication of the common bean, field experimental design, visualizing data using RStudio, and culinary uses of wheat. Presentation about the SCOPE breeding program at the Plant Breeding Retreat in 2023 Attending the 2023 Organic Seed Summit in San Anselmo. Presentations about the SCOPE project to PLS 2 classes in Winter Quarter 2023 and PLS 12 in Spring Quarter 2023. Organizing and presenting at the Organic Grains Field Day in 2022 which was attended by approximately 30 participants and included a taste test of whole wheat dinner rolls and conchas. Coordinating and presenting at the SCOPE Field Day in 2022, which was attended by 45 people. Coordinated and participated in a whole grains tasting event \"All About Grains\" through the Sips & Bites series at the Robert Mondavi Institute, with approximately 50 participants tasting cookies and crackers made using triticale, naked barley, and UC Amarillo wheat. What do you plan to do during the next reporting period to accomplish the goals?The project will continue advancing breeding germplasm of zinnia, tomato, wheat, and celtuce. Final data will be generated for pepper to release cultivars in 2024. Impacts What was accomplished under these goals? Obj. 1. The tomato program is producing improved heirloom type fresh market tomatoes for organic production in California. The tomato program includes both inbred (open-pollinated) and hybrid cultivar development at UC Davis and Cal Poly Pomona. The specific breeding objectives include (1) a red slicer tomato with high yield and stacked disease resistances using marker assisted selection, and (2) tomatoes with appealing heirloom colors and/or shapes. In both cases, excellent flavor and texture are also selection criteria. The program conducts multi-location replicated trials of advanced inbred lines and F1 hybrids to identify possible cultivar releases. Cultivars in replicated trials are scored for fruit quality traits, including sun scald, cracking, blossom end rot, fruit firmness, and BRIX, in addition to yield. Marker assisted selection is also used to select inbred progeny with desirable disease resistance markers. We also conduct on-farm strip trials of our advanced materials with organic farmers. Taste panels assess the flavor and consumer perception. The program is expected to release at least 4 new tomato cultivars, including \'Orange Creamsicle\' and \'Rockin\' Roma. The zinnia program has developed and refined techniques breed zinnias, including phenotyping methods, crossing protocols, and field management. The breeding program is divided into four breeding groups targeting specific trait combinations: improved \'Queen Lime\', pastel, bi-color cactus, and smaller \'Benary\'s Giant\'. Cultivars with these traits would fill supply gaps in the current zinnia marketplace and the goals were developed with direct input from growers. Our experimental populations have been evaluated in replicated trials on the UCD Student Farm for stem length, flower size, post-harvest vase life, and disease resistance. The program is expected to release at least 4 new zinnia cultivars, out of 10 promising breeding populations that have been identified. The wheat breeding program focuses on spring wheat planted in the fall in California. Organic growers, millers, and bakers are primarily interested in cultivars with unique qualities, improved yield, disease resistance, and high protein under low inputs. Quality is a strong focus of wheat cultivar development for SCOPE, and students participate in quality testing at the California Wheat Commission (CWC), a grower funded organization in Woodland, CA, with an on-site quality and baking laboratory. These tests include evaluation of both grain and flour traits such as protein, ash, falling number, SDS sedimentation, mixograph, and baking tests. The program is dived into two main populations: Heritage . Modern: Improving weaker aspects of heritage lines (disease resistance, lodging, yield, and quality) while retaining positive traits (early vigor, weed competition, drought tolerance, and unique quality and flavor) High anthocyanin . Modern population: High anthocyanin wheats with blue, purple, and dark red seed coats have increased antioxidants and can produce unique colors for whole-wheat baked goods. Some specific items: We managed approximately 1/2 of an acre of field trials of zinnias, tomato, and celtuce at the UC Davis Student Farm and on-farm trials of tomatoes and celtuce. Developed and implemented a protocol for outdoor, isolated zinnia seed production using blue bottle flies. Collected yield data for 22 advanced tomato breeding lines, 57 tomato breeding lines (F1-F5) Collected data on 29 zinnia breeding populations for stem length, vase life, and color including for 11 advanced zinnia breeding lines. Conducted and collected data for a replicated trial and seed

increase of 39 advanced wheat breeding lines. Planted a celtuce demonstration plot at the Student Farm\'s Eco Garden to educate the public on the goals of this breeding project, a new addition to SCOPE in 2023. Developed a collaboration with Prof. Ga Young Chung in the Department of Asian American Studies and the Second Generation Seeds collaborative to test and make selections from 14 celtuce F2 populations on-farm and at the Student Farm as part of a farmer participatory breeding project. Obj. 2. During the study period, seven graduate students and 17 undergraduate students participated in SCOPE, bringing the total number of students for the entire project to 50 undergraduate and 15 graduate students in internship, volunteer, and paid student positions at UC Davis and Cal Poly Pomona. These students have been training in plant breeding principles, organic farming methods, and cultural awareness of different food systems. Obj. 3. During the study period, we conducted on-farm trials for tomatoes and celtuce. We attended the California Organic Seed Summit to discuss the SCOPE project with organic seed growers, presented SCOPE progress at the annual UCD Plant Breeding Retreat, and hosted two field days of SCOPE projects. We developed breeding agreements with several small seed companies. Publications Progress 09/01/21 to 08/31/22 Outputs Target Audience:In the second year of the SCOPE 2.0 project, we hosted events and crafted outreach materials targeting our large network of students, faculty, plant breeders, seed producers, organic farmers, and other stakeholders tied to the Organic Seed Alliance\'s and California Wheat Commission\'s networks. Our undergraduate internship program built on previous quarters\' experiences to gain more independence and leadership roles, and increase undergraduate-faculty interaction. The student-led breeding projects created opportunities for graduate students across disciplines to participate in field management and breeding concepts, data collection, seed production, and fruit processing. The projects also increase student understanding of the practice and theory of plant breeding, and strengthen the participatory network of stakeholders engaged in this project. In partnership with OSA, our events have been attended by a network of organic seed producers and seed companies, organic farmers, researchers, food company representatives, and other stakeholders. Each spring, OSA also helped coordinate outreach with partnering regional organic farms to coordinate variety trials. We also continue to highlight project outcomes through the SCOPE website (https://plantbreeding.ucdavis.edu/scope- project), and shared through partner websites, social media, and listserves. Changes/Problems:The project is progressing well and all aspects are moving according to plan. We intend to apply for a renewal of the program in the coming year. What opportunities for training and professional development has the project provided?The project has provided training in plant breeding and organic crop production for numerous graduate and undergraduate students, with in-depth training for the breeding team lead students who participated for at least a year on the project. Further, the two staff members who provide hands on organization gained leadership skills through their involvement with the project. How have the results been disseminated to communities of interest?We have organized several field days during the time frame attended by students, growers, and extension personnel. We also had one-on-one interactions with several seed companies interested in growing seeds of our cultivars as well as interested farmers and companies who want to participate in breeding activities. What do you plan to do during the next reporting period to accomplish the goals?We will continue the tomato, wheat, zinnia, and pepper projects, developing new crosses, evaluating advanced generations of breeding lines, and collecting data for selection and possible cultivar release. We will contact more seed growers and farmers interesting on trialing our experimentals on-farm. Impacts What was accomplished under these goals? Objective 1. Breeding continued on pepper, tomato, wheat, and zinnia. Three pepper experimentals have performed well on farms as well as on our campus student farm, both agronomically and in taste tests. These will be moved forward for release. For tomatos, we began testing hybrids along with inbred cultivars, and several desirable hybrids were identified from evaluations this summer. About 40 wheat lines are being evaluated for possible on-farm trials with interested stakeholders, including several very lovely blue wheat lines. Approximately ¾ of an acre of field trials of tomatoes, wheat, zinnias, tomatoes, bell peppers, and jalapenos at the UC Davis Student Farm and an on-farm trial of tomatoes in the Sacramento Valley were planted. A zinnia demonstration plot at the Student Farm\'s Eco Garden to educate the public on the goals of this breeding project. Collected yield data for 38 advanced tomato breeding lines and 52 tomato early generation breeding lines (F2-F4) and 3 pepper varieties. Collected data on flower color, petal shape, stem length, and other traits for 30 zinnia breeding populations. The zinnia breeding project team developed and implemented new phenotyping protocols on zinnia vase life and powdery mildew disease severity. Managed a sweet potato variety trial, which we assessed as a possible new crop for SCOPE. Maintained crossing blocks for tomatoes and zinnias. Held a tomato taste test to evaluate 34 advanced breeding lines for flavor, texture, and appearance. Objective 2. We have had five graduate students act as lead breeders and four additional graduate students have been involved with breeding projects. About 30 undergraduate students participated in the past year. Objective 3. We hosted a field day in Fall 2022 for all SCOPE crops and an Organic Wheat Field Day in spring 2022. On-farm trials of tomatoes continued in 2022. Several seed companies are interested in collaborating on breeding zinnias and in producing seed for pepper releases. We also held a hybrid on-line/in-person seminar series on organic breeding, food production, food preparation, and seed sovereignty Publications **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience:In the first year of the SCOPE 2.0 project, we hosted events and crafted outreach materials targeting our vast network of students, faculty, plant

breeders, seed producers, organic farmers, and other stakeholders tied to the Organic Seed Alliance's and California Wheat Commission's networks. Our undergraduate internship program built on previous quarters' experiences to gain more independence and leadership roles, and increase undergraduate-faculty interaction. The student-led breeding projects created opportunities for graduate students across disciplines to participate in field management and breeding concepts, data collection, seed production, and fruit processing. The projects also increase student understanding of the practice and theory of plant breeding, and strengthen the participatory network of stakeholders engaged in this project. In partnership with OSA, our events have been attended by a network of organic seed producers and seed companies, organic farmers, researchers, food company representatives, and other stakeholders. This spring, OSA also helped coordinate outreach with partnering regional organic farms to coordinate variety trials. We also continue to highlight project outcomes through the SCOPE website (<https://plantbreeding.ucdavis.edu/scope-project>), and shared through partner websites, social media, and listserves. Changes/Problems:Despite the pandemic, we have managed to keep the breeding programs largely on track due to much of the work being done outside and/or in greenhouses with ample space to physically distance participants. The program is on track in all respects. What opportunities for training and professional development has the project provided? The major training activity for this grant is the internship program for undergraduate students and training of graduate students to be plant breeders. Due to COVID-19, our internship program at Davis was remote during summer 2020, and had a remote option during the '20-'21 school year. Each week, the undergraduate students attended at least one 1 hour meeting, where they either heard from a speaker or held a \"work group\" meeting to discuss their projects. Seminar speakers presented topics related to plant breeding or the crops of interest. Work groups were student-led, so that students could gain confidence in facilitating meetings, an important skill in a workplace. A total of 50 seminars or work groups were held. Outside of weekly meetings, in-person students were trained in hands-on plant breeding and organic farming skills, such as crossing, making single plant selections, data collection, transplanting, weeding, and more. Remote students were trained in computer-oriented skills, such as data entry, data analysis, making selections based on data, and developing content to share with the public, such as social media posts and educational videos. A total of 15 students completed an internship with SCOPE at UC Davis: 6 were completely remote and 11 had some in-person component. Two other students completed in-person internships at Cal Poly Pomona, focusing on field and greenhouse management. Graduate students have the opportunity to lead teams for each crop and are ultimately responsible for the direction and decision-making within each project. Seven graduate students were leads, or took an equivalent leadership role. Two students completed their PhDs this year after being team leads in SCOPE for at least 3 years. How have the results been disseminated to communities of interest? We presented information through numerous seminars, field days, invited presentations, and other outlets. Due to the pandemic, all of these events were virtual, including the a presentation at the California Seed Summit, a panel of 15 zinnia growers to discuss breeding needs and goals, a presentation to the introductory plant breeding class at UC Davis, a virtual wheat field day, including seminar presentations by PI Brummer virtually at the Univ. of Minnesota and at Clemson Univ. What do you plan to do during the next reporting period to accomplish the goals? In the next reporting period, we will continue to advance the breeding lines for all crops. While the wheat, tomato and zinnia programs are still some way from release, we have several pepper lines that we will collect more data for potential release. In addtion, we will evaluate sweet potato lines to determine if this is a new crop we want to add to the program (as a clonally propagated crop, it would be very complementary to our existing species and offer students another crop model. We intend to continue our student internship program and to invite participants from outside the university to attend our seminars. We hope to have in-person field day events in 2022, pandemic willing. **Impacts** What was accomplished under these goals? Zinnia: In summer 2020, the Zinnia project began its evaluation of available germplasm and began making initial crosses. The project evaluated 40 different accessions and produced 195 different biparental crosses. These crosses were also the basis for crossing and seed saving protocol, as well as educational videos and demos for zinnias. In fall 2020, larger objectives for the zinnia project were established and target traits are selected. With direct input from growers, 5 primary traits were selected for improvement: color, petal shape, flower size, stem length and disease resistance. To accomplish these goals, crosses from the initial pool were selected and organized into 4 \"breeding groups\" which targeted one or multiple traits for improvement. In total, 40 promising families were selected based on the phenotypes of the parents. In winter 2020/2021, a greenhouse planting of zinnias was conducted to explore the inheritance of certain target traits not described in existing literature, as well as explore inbreeding depression in self-pollinated lines. 10 crosses were selected from the initial pool of field crosses and were grown in the greenhouse, along with their parental lines and new germplasm additions, or 40 additional plants. In total, and additional 53 crosses and selfs were conducted. In spring 2021, preparation and planning for the summer field planting took place. In addition to the 40 lines selected based on breeding goals, 12 accessions of new germplasm were planted to add additional genetic diversity into the program, as well as genes that aligned with the overall breeding program. 8 lines were also added that showed promise but didn't fit into any specific goal, and 9 lines were selected by SCOPE interns to demonstrate and educate on the process of seed selection. In total, initially 863 plants were grown on a quarter-acre field, and an additional 63 plants were added from the

greenhouse crosses, bringing the total field planting to 926 zinnias. After reaching maturity, the zinnias were individually phenotyped by color, and additional phenotyping will take place in summer 2021. Tomato: In Fall 2019-Winter 2020, an off-season greenhouse crossing block was initiated to advance selections from the 2019 field and to generate crosses. Thirty-five crosses were made in order to produce new breeding material for generating inbred lines. During Spring 2020, the SCOPE tomato project prioritized the following traits for its inbred lines: fruit size (slicer-type), disease resistance, flavor, and fruit color. The ideotypes that SCOPE aims to create are an heirloom-type red slicer with improved disease resistance and yield, and a colorful heirloom-type with good flavor, improved fruit quality, and improved disease resistance and yield. Approximately 1,000 tomato plants were planted in the field, which included 45 F1 crosses, 10 families ranging from F2 to F7, 4 checks, and 26 new introductions. During Summer 2020, the field was phenotyped for fruit ripening date, fruit abundance, fruit weight, fruit color, flavor, blossom end rot, sun scald, canopy thickness, height, and prevalence of disease. In total, 60 selections were made from the field. Eleven crosses were made in the field to produce new breeding material for generating inbred lines. During Fall 2020-Winter 2021, cuttings from field selections were used for a crossing block during the off-season to advance selections from the 2020 field and to generate crosses. Seventy-eight crosses were made in order to produce new breeding material for generating inbred lines. During Winter 2021, the SCOPE tomato project began an initiative to include hybrid breeding into its program. This involved compiling 20 inbred lines from SCOPE and our collaborators to trial in different locations, including on-farm trials conducted by growers. During Spring 2021, approximately 1,500 plants in the field, with one-third of the field consisting of replicated plots of the 20 inbred lines. Six of the 20 lines have been selected to conduct a diallel based on fruit size and preliminary performance to assess combining abilities. During Summer 2021, cuttings of the 6 lines selected for the diallel had cuttings taken to initiate a crossing block, in addition to 6 other lines to complete crosses that could not be made during the crossing block of Fall 2020-Winter 2021. Plants will phenotype throughout the summer for similar traits as Summer 2020 in addition to Brix, yield, and flavor testing. Pepper: In summer 2020, the pepper project tested 4 jalapeno lines and 3 bell pepper lines against 3 jalapeno checks and 4 bell pepper checks at 2 farms. Due to COVID-19, we did not have an additional trial at the UC Davis Student Farm. Based on marketable yield data from these two locations, we selected two jalapeno lines and one bell pepper line to prepare for release in 2021. The bell is a short, yellow variety that is late-maturing and sunscald resistant. The jalapeno pepper \"popper\" has thicker and wider pericarp than all 3 jalapeno checks and is moderately spicy, making it excellent for jalapeno poppers. The other \"frying\" type pepper, is a large, moderately spicy pepper that also performed well at both locations, although it's larger than most jalapenos. For yield, both lines had a higher yield per plant than both Early Jalapeno and Jalapeno Grande. The bell pepper line had the highest per plant marketable yield and lower sunscald % than Golden California Wonder and Red Knight (10.3% versus 14.3-39.6%). In winter 2020-2021, we planted 2 generations of each of these 3 lines for a seed increase. The earliest generation material is F6, for the frying pepper, and the latest generation is F10, for the popper and bell pepper. In summer 2021, we planted strip trials at 4 locations: 1 at Cal Poly Pomona, 1 at the UCD Student Farm, and 2 at the same farms in Yolo County as 2020, Each location has about 20-40 plants of each line and corresponding check varieties. We plan on collecting the necessary phenotype data for each line to pursue a plant variety protection, in addition to collecting data on fruit size, color, shape, and plant yield. We plan on releasing the varieties in 2022. We will save seeds from caged plants in the field and in our greenhouse.? **Publications**

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Plant Safety, Horticultural Benefits, and Disease Efficacy of Essential Oils for Use in Organically Grown Fruit Crops: from the Farm to the Consumer

Accession No.	1023533
Project No.	FLA-HOS-005980
Agency	NIFA FLA\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51300-32181
Proposal No.	2020-02141
Start Date	01 SEP 2020
Term Date	31 AUG 2024
Grant Amount	$1,999,317
Grant Year	2020
Investigator(s)	Sarkhosh, A.; Crane, JO, HE.; Schnabel, GU, .; Brecht, JE, .; Treadwell, DA, D.; Keith, LI, M.; Schaffer, BR, .; Oliver, JO, .; Carrillo, DA, .; Melgar, JU, .; Manosalva, PA, .; Gazis-Seregina, RO, .; Williamson, JE, G.; Harmon, PH, F.; Kawabata, AN, .
Performing Institution	UNIVERSITY OF FLORIDA, G022 MCCARTY HALL, GAINESVILLE, FLORIDA 32611

NON-TECHNICAL SUMMARY

This Multi-Regional Integrated Research and Extension Project addresses two OREI focus areas: 1) Facilitating the development and improvement of organic agriculture production, breeding, and processing methods and 6) Conducting advanced on-farm research and development that emphasizes observation of, experimentation with, and innovation for working organic farms, including research related to production, marketing, food safety, socioeconomic conditions, and farm business management development of new integrated management tools. A trans-disciplinary team of plant pathologists, horticulturists, a whole-plant physiologist, a postharvest biologist, an entomologist, extension specialists, and certified organic fruit growers will investigate solutions to improve the feasibility of organic fruit production by substantially reducing the risk of producing organically grown fruit crops relative to disease development. This will be achieved through laboratory, field, and postharvest evaluation of the effectiveness of these organically certified plant essential oils (EOs) on targeted pathogens such algal stem blotch (Cephaleuros virescens Kunze ex E.M.Fries), brown rot (Monilinia fructicola Winter), scabs (peach scab: Cladosporium carpophilum Fisher, avocado scab: Sphaceloma perseae Jenkins), anthracnose (Colletotrichum spp), gray mold (Botrytis cinerea Pers), powdery mildew (avocado: Oidium spp., mango: O. mangiferae), bacterial spot (Xanthomonas arboricola), and stem blight/ gummosis (Botryosphaeria dothidea Moug.: Fr and related species) in targeted temperate and tropical fruit crops (blueberry, peach, avocado, and mango), and in five states (Florida, Georgia, South Carolina, California, and Hawaii). While arthropod pests are not the primary focus of this research, we will also test the efficacy of EOs against arthropods, including scales, thrips, and mites. The project will determine the efficacy of these EOs and the best application rates and timing for the most efficient disease control. This will increase organic orchard productivity, low-residue fruit crops, and offer an organic spray program using organic plant EOs. This project is expected to contribute to both long-term profitability and sustainability of organic fruit crop production as the future of copper- and sulfur-based pesticides is limited.

OBJECTIVES

Goal:1. Facilitating the development and improvement of organic agriculture production, breeding and processing methods.6. Conducting advanced on-farm research and development that emphasizes observation of, experimentation with, and innovation for working organic farms, including research related to production, marketing, food safety, socioeconomic conditions, and farm business management.Objectives:1: To evaluate plant safety and potential plant disease control efficacy of plant essential oils (EOs) applications in selected fruit crops through in vitro (laboratory assays), incubator, and greenhouse experiments.2: To test on-farm disease suppression of applications of various concentrations and mixtures of EOs on peach, blueberry, mango, and avocado through multi-year experiments.Objective 3: To determine the efficiency of EOs applications on fruit shelf life through postharvest assays and experiments.Objective 4: To communicate and disseminate results to organic fruit and conventional growers in a manner that stimulates rapid adoption of practices and to evaluate the effectiveness of the project through a continuous feedback loop from stakeholders.Organic fruit growers in the United States (U.S.) are often hesitant to embrace organic practices due to the shortage of operative tools for disease management. Certified organic farmers who produce fruit crops, such as peach, blueberry, mango, and avocado, struggle to protect their plants and fruit from overwhelming pressures caused by diseases such as brown rot (Monilinia fructicola, Dothiorella theobromae, and others), scab (Elsinoë mangiferae), anthracnose (Colletotrichum gloeosporioides), powdery mildew (Oidium mangiferae), gray mold (Botrytis cinerea), and stem blight and stem rot (Botryosphaeria spp.). This project will evaluate the plant safety and horticultural impact of essential oils (EOs) for disease management and will begin to test plant disease efficacy claims of EO products currently marketed for organic producers. Results from this work will apply to most organic fruit growers in the United States, specifically in those areas that experience relatively high temperatures and humidity during part of the crop cycle (e.g., Alabama, California, Florida, Georgia, Hawaii, Louisiana, South Carolina, Texas, Puerto Rico, and the Virgin Islands). The long-term goal of this project is to provide U.S. organic fruit growers with safe, organically certified compounds for disease management, and consequently improve their confidence in plant-based fungicide, bactericide, and insecticide applications.

APPROACH

To evaluate plant safety and potential plant disease control efficacy of plant essential oils (EOs) applications in selected fruit crops through in vitro (laboratory assays), incubator, and greenhouse experiments.Using isolates of common and destructive pathogens affecting the targeted fruit crops, disease suppression and physiological effects of foliar EOs applications will be determined.We will test the commercial products Thyme Guard containing thyme oil and Timorex Gold containing tea tree oil, both labeled in the U.S. as broad-spectrum organic fungicides against plant diseases.In-vitro screening. Fungi will be isolated from diseased samples, under sterile conditions and after surface sterilization treatments. Pathogen identification will be conducted by morphological examination of macro and micro characters and comparison of DNA sequences, corresponding to the Internal Transcribed Spacer (ITS) and the Translation Elongation Factor 1 (TEF-1) regions, to those of reference isolates following protocols described in Gazis et al. (2014).Detached leaf/stem screening assays. Leaves for the assay will be collected from greenhouse-grown fruit crops, using protocols based on Conner (2012). The tested products will be applied to leaf discs in aqueous solutions of various concentrations to establish the dosage range preventing the sporulation of the pathogen without harming plant tissue. Essential oils will be tested alone and in combination.Essential oils screening on fruit crop seedlings in glasshouse conditions. Efficacy fungicidal activity will be tested on container-grown plants (same cultivars used in the detached leaf/stem assay experiment) under greenhouse settings. Plants will be treated with EOs when 3-4 leaves become fully expanded. The EOs will be applied with a hand or backpack sprayer. Each EO will be tested in at least three concentrations (based on in vitro assays).Testing EOs for controlling insects through laboratory bioassays. Field populations of spider mites (O. yothersi and T. urticae), thrips (F. occidentalis), San Jose Scale (Q. perniciosus), and mango scale (A. tubercularis) will be collected to establish colonies at the University of Florida, TREC, Fruit Entomology laboratory. Each insect or mite population will be reared for at least three generations before assessing their susceptibility to EOs. Leaf bioassays will be used to test the effect of EO residues on the survivorship of each insect or mite.To test on-farm disease suppression of applications of various concentrations and mixtures of EOs on peach, blueberry, mango, and avocado through multi-year experiments. On-farm plant disease control efficacy of EOs will be determined using 2-3 product rates selected from objective one. The selected EO rates for each crop will be compared to standard growers\' practices in the certified organic orchards where the trials will be conducted (see attached support letters). Arthropod pests are not the key focus of this research, but any incidental visual damage or activity in the field caused by arthropods will be quantified and results will be considered for future research. Experiments will be set up in a randomized complete block design or a completely randomized design, depending on the configuration of the orchard. Applications will be made according to the product labels and grower practices using an air-assisted sprayer (either a compressor-based spray system or a

portable motor sprayer) until near run-off. The effect of our treatments (standard or EOs) on tree growth, yield, and fruit quality is expected to differ based on the growing conditions (recent and current), but plot size in the same location is not expected to increase the accuracy of the results. Thus, determination of phytotoxicity, tree growth, yield, fruit quality, and disease assessment will be done in subplots consisting of 3-5 replicates (individual trees per orchard), each distributed across the entire orchard. These trees will be selected randomly and flagged at the beginning of the study before applying the treatments. In field assessments of the disease incidence and severity within plots and across treatments will be quantified and recorded throughout the year, for two years. Severity and incidence will primarily be recorded on a 0 to 100% visible rating scale or as a proportion of the total plant organs rated. Multiple ratings per plant, per stem, and individual leaves or fruit as deemed appropriate by the lead PI at the location will be chosen to maximize potential for illustrating between-treatment differences. Representative samples exhibiting disease symptoms will be collected and diagnosed (HI) or submitted to the university\'s Plant Disease Clinic for diagnosis. Pathogen isolates from the field trial samples will be maintained in the culture collection and evaluated for in vitro sensitivity to EOs as described above.To determine the efficiency of EO applications on fruit shelf life through postharvest assays and experiments. Postharvest fruit decay incidence, fruit quality, and sensory evaluation for all fruit crops as affected by treatments in the field (in situ) and in the lab (in vivo) will be determined. The use of different EO application methods for improving the fruit postharvest life will be tested (University of Florida). Postharvest assays will also be carried out in each state to determine for how long fruit treated with EOs in the field remain disease free on the shelf compared to those treated with growers\' standard treatments. Experiments will be carried out on freshly harvested fruit (from the same cultivar used for field assays). Fruit at commercial harvest maturity will be randomly picked from each experimental tree and plant, and stored for 7 to 14 days as appropriate for each fruit type. After each experiment, causal agent of postharvest disease will be confirmed by isolating the pathogen from affected tissue and barcoding the strain. **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience:Project team in their states have been communicating with project farm collaborators via phone, email, and farm visits (12 farms). Communication of (preliminary) project results is anticipated to begin in year 2. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Three postdocs were recruited and trained to conduct experiments in lab, greenhouse and filed. The two in plant pathology have been investigating antifungal activity assays for Thyme Guard and Timorex Gold against pathogen in blueberry, peach, avocado and mango. A postdoc in entomology has been studying performance of commercial formulations of essential oils to control Lace bug in Avocado. A Ph.D. student was required and trained with hands on in pathogen isolation, growth and fruit inoculation to investigate performance of commercial formulations of essential oils to control postharvest decay in peach and blueberry. Two MS student were recruited and trained to work on filed evaluation commercial formulations of essential oils in peach and blueberry in South Carolina and Georgia. The student is scheduled to start fall semester of 2021. Subaward accounts were set up to initiate the project. Three biological scientists and 4 OPS have been gaining additional training to enhance their professional development in their position. How have the results been disseminated to communities of interest?At the annual team and advisory members meeting, project development was discussed. A poster titled \"Mango and avocado anthracnose: A major challenge for organic fruit production in south Florida\" was presented at 98th Southern Division Meeting/American Phytopathological Society in February 2021. An oral presentation tilted \"Evaluation of thyme oil vapor for control of postharvest gray mold on blueberry\" in Annual meeting of Florida State Horticultural Society in September 2021. Project team in their states have been communicating with project farm collaborators via phone, email, and farm visits (12 farms). Communication of (preliminary) project results is anticipated to begin in year 2. What do you plan to do during the next reporting period to accomplish the goals?Detached leaf/stem screening assays, leaves for the assay will be collected from greenhouse-grown fruit crops, using protocols based on Conner (2012). Efficacy fungicidal activity will be tested on container-grown plants in greenhouse. Testing EOs for controlling insects through laboratory bioassays will be performed. On-farm plant disease control efficacy of EOs will be determined using 2-3 product rates selected from objective one. The selected EO rates for each crop will be compared to standard growers' practices in the certified organic orchards. Postharvest fruit decay incidence, fruit quality, and sensory evaluation for all fruit crops as affected by treatments in the field (in situ) and in the lab (in vivo) will be determined. At the annual team meeting, advisory members will discuss project development, review project outputs and the annual evaluation summary and recommend changes. Presentations and extension activities with focus on the application of findings relevant to local outcomes. **Impacts** What was accomplished under these goals? Obj.1: Blueberry and peach: The antifungal activity assays for Thyme Guard and Timorex Gold were carried out on Potato Dextrose Agar (PDA). Each product was added to autoclaved PDA (at the final EO concentrations of 0, 17.25, 34.5, 69, 138, and 276 µlL-1). These concentrations were chosen after preliminary assays that showed high growth inhibition with Thyme Guard amended PDA for a few of our isolates. The trial assays also showed isolate growth inhibition decreased after the third day. Overall 11 fungal isolates were tested. Three replicate plates for each concentration were used per isolate and two growth diameter measurements were taken for each test plate at 24h time interval until Day 3. Thyme Guard amended plates displayed high to complete inhibition of all isolates

growth, especially on Day 1 and Day 2 and at EO concentration 138 and 276. In contrast, Timorex Gold seems to enhance isolates growth at all concentrations (hormosis), especially on Day 2 and 3 and at high EO concentrations. The EC50 estimates and R square values for our Colletotrichum isolates (T5-5-9-15, SY(one), MR1 and Mr2) tested against ThymeGuard and a graph showing the relative growth of the isolates when tested against Timorex Gold. The estimates for the rest of the tested isolates are in progress. Mango and Avocado: Sixty isolates of Colletotrichum spp., \"anthracnose\", were obtained from diseased tissues (fruits, leaves, and twigs) of avocado and mango in Florida, Hawaii, and California. Isolates that successfully produced spores on culture media were further purified as single-spore isolates, confirmed as Colletotrichum spp. by examination of morphological characters, and stored (-80°C). Pathogenicity tests were conducted to assess aggressiveness among the collection of Colletotrichum isolates from mango and avocado. The more aggressive isolates (5 per crop) will be used in the in vitro screening the fungicide activity of EOs, using the selected concentration ranges. Preliminary experiments, using two representative isolates, were conducted to select an adequate range of EOs concentrations for the in vitro the fungicide assays. The commercial formulations Thyme Guard and Timorex were diluted in sterile water and added to molten PDA at about 50°C to obtain final concentrations ranging from 0 (non-amended control) to 1200 μl.L-1, based on previous published postharvest experiments (Sarkhosh et al. 2017, 2018a,b). Five-millimeter diameter mycelial plugs were cut from the margin of 7-days old Colletotrichum colonies and were transferred to five replicate plates of each EOs concentration. Percent of fungal growth inhibition at each EOs concentration was calculated in relation to fungal growth observed in the non-amended controls at 7 days after inoculation. Fungal growth inhibition values were fitted to a four-parameter log-logistic model using the 'drc' package in the software RStudio (Ritz et al. 2015) to estimate the effective concentrations causing 50% inhibition of mycelial growth (EC50 values), as well as the minimum inhibitory concentrations (MIC) per EO. Fungal growth was not observed at concentrations equal or higher than 652 μl.L-1, 300 μl.L-1, and 300 μl.L-1, for the commercial formulation Thyme Guard, and the pure formulations of thyme oil and savory oil, respectively. Interestingly, the MIC concentration value observed for Thyme Guard only contains about 150 μl.L-1 of thyme oil (i.e., 23% active ingredient). If compared to the MIC observed with the pure formulation of thyme oil (i.e., 300 μl.L-1), the concentration of thyme oil required to achieve MIC with the product Thyme Guard is a half time lower. This result might be partly due to a potential fungicide action of the additional inert ingredients present in the Thyme Guard formulation used (e.g., sodium citrate).On the other hand, fungal growth was observed in all the concentrations tested for Timorex which contains 12.5% tea tree oil. Additional tests using higher concentrations of Timorex showed that the MIC for this commercial product are higher than 27,000 μl.L-1 (≈ 3,400 μl L-1 tea tree oil). Timorex at concentrations of 27,000 μl.L-1 and 54,000 μl.L-1 (2x and 4x the highest rate recommended in the label, respectively) were sprayed onto leaves of potted mango and avocado plants to further explore potential phytotoxicity damage at rates ≥ 27,000 μl.L-1. At these two rates, phytotoxicity was observed on leaves and flowers, on both crops. Therefore, the Timorex manufacturer recommended high rate (i.e., 13,500 μl.L-1 Timorex will be considered as the highest concentration to be evaluated in next experiments with this compound. Detached leaf assays: Target spot on blueberry: Plant material (Optimus & Sentinel varieties) were ordered and arrived late July. However, these are currently too small to use for detached leaf assays. They were transplanted and are currently growing in the greenhouse. Half are to be fertilized, while the other half are to be used for modified leaf assays using the whole plantlets. Although delayed by the slow growth and sporulation of our Corynespora isolate, the assays will be performed soon. Rust on peach: Clean leaf material (no fungicide) is needed as soon as possible. Rust spores also need to be collected before September for the assays to be completed. Performance of commercial formulations of essential oils to control the Avocado Lace bug The widely used conventional insecticides Danitol® and Imidacloprid® were highly effective in controlling ALB. ThymeGuard® (Thyme oil) and Stylet® (mineral oil) were the most effective alternatives to conventional pesticides for ALB control. The essential oils Agropest®, Timorex®, and Armorex®, showed low insecticidal activity against ALB. ThymeGuard® and Stylet® should be reapplied to obtain better control. The essential oil ThymeGuard® is an alternative to conventional insecticides to manage the avocado lace bug. However, effective control may require repeated applications. Obj. 2: High and low rates of Timorex were used for two applications at 1.5 months interval (using 4 gal jugs and compressor-based spray system). The same system was used for Thyme Guard at recommended high label rate and \~3x rate at the first application. On blueberry, a Higher (5x) rates of both Timorex and Thyme Guard are detrimental to fruit development and quality in blueberry. In peach, higher (\~3x) rate of Thyme Guard also seems to have minimal effect on tree flowering/foliage emergence/fruit. ThymeGuard and Timorex treatment rates were the highest and lowest recommended concentrations and a concentration in the middle for mango and avocado. Phytotoxicity data was collected weekly from the time of spraying to 1 week after spraying was completed. No phytotoxicity was observed in any of the treated branches. Obj. 3: Trees were sprayed to runoff (4.5 gal/tree) at 100 psi with a handgun sprayer on 27 May 5 Jun, and 11 Jun. Decay was calculated as a percentage 3 and 7 days postharvest (dph). OSO 5%SC applied at 13 fl oz reduced preharvest but not postharvest brown rot compared to the control, however, in combination with 0.25% ThymeGuard no reduction in disease was recorded either preharvest or

postharvest. OSO 5%SC caused significant defoliation of older leaves leading to blind nodes on branches and its combination with 0.5% PureSpray (a highly purified mineral oil) exacerbated this effect. The mixture with 0.25% ThymeGuard, however, did not cause this negative effect. Obje. 4: Project team in their states have been communicating with project farm collaborators via phone, email, and farm visits (12 farms). Communication of (preliminary) project results is anticipated to begin in year 2. **Publications** - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Mango and avocado anthracnose: A major challenge for organic fruit production in south Florida Thais G. Egreja, Jonathan Crane, Bruce Schaffer, Ali Sarkhosh, & Romina Gazis. (2021). Mango and avocado anthracnose: A major challenge for organic fruit production in south Florida. The 98thannual meeting of the American Phytopathological Society, Southern Division,virtually from February 15-19, 2021.

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Quantifying the Nitrogen Cycling Benefits of Different Cover Crops Across Different Florida Organic Vegetable Production Systems

Accession No.	1023583
Project No.	FLA-SWS-005985
Agency	NIFA FLA\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51300-32184
Proposal No.	2020-02119
Start Date	01 SEP 2020
Term Date	28 FEB 2023
Grant Amount	$496,271
Grant Year	2020
Investigator(s)	Maltais Landry, G.; Zhao, XI.; Wilson, CH, H.; Strauss, SA, L.; Grabau, ZA.
Performing Institution	UNIVERSITY OF FLORIDA, G022 MCCARTY HALL, GAINESVILLE, FLORIDA 32611

NON-TECHNICAL SUMMARY

Organic vegetable systems face many challenges, including the lack of affordable water-soluble fertilizers to optimize nutrient management, especially nitrogen. These challenges are exacerbated in Florida\'s sandy soils, which are subject to a subtropical climate that favors nitrogen losses and pests, such as plant-parasitic nematode pressure. Cover crops can improve nitrogen availability but nitrogen inputs via biological nitrogen fixation and subsequent transfer to vegetable crops remain poorly quantified. Cover crops can also reduce nematode damage while benefitting soil health and microbial communities. However, benefits from cover crops are likely system-specific, with potential trade-offs among these different benefits. This interdisciplinary project will quantify the benefits of four different cover crops for three Florida vegetable crops with a variable growing season length: bok choy, cucumber, bell pepper. These systems will be subject to nutrient management based on composted poultry manure used alone (\"manure\" systems) or combined with processed fertilizers and nitrogen credit from cover crops (\"integrated\" systems). We will assess nitrogen cycling, crop yields and quality, nematode and microbial communities, and soil health. We will seek grower feedback through an interactive field day, educate extension agents and other professionals during a professional training workshop, and develop traditional extension documents and online videos to disseminate key results. Our holistic approach will allow us to better understand the effects cover crops have on organic vegetable production in the Southeast in order to optimize their use in challenging soil and climatic conditions and improve nutrient cycling, crop productivity, and soil health toward long-term sustainability. Ultimately, our research should help increase yield and crop quality while reducing inputs of fertilizer and pesticides.

OBJECTIVES

The overarching goal of this proposal is to identify under which conditions cover crops provide the most benefits to organic vegetable production in Florida. The proposed research will focus primarily on N benefits provided by cover crops and how they interact with other aspects of organic production: crop yields and quality, nematode pressure, microbial communities, and soil health. Specific objectives of this interdisciplinary project are to: Determine the influence of cover crop combinations and nutrient management approaches on N cycling and availability for vegetable crops with different growing season length and nutrient requirements; Quantify the

effects of different cover cropping systems on crop quality, soil nematodes, microbial communities, and soil health indicators in organic vegetable production; Share key outcomes with growers, extension agents and the broader community through field activities, extension publications, online videos, and a professional development workshop

APPROACH

Field experiment for objectives 1 and 2We will establish a two-year experiment with a split-split plot design with five cover crop treatments as the main plot, three vegetable crops as the subplot, and two nutrient management approaches as the sub-subplot. Cover crop treatments will consist of a monoculture of sunn hemp, a biculture of sunn hemp with sorghum sudangrass or millet, and a mixture of sunn hemp, millet, sorghum sudangrass, and sesbania; an unplanted fallow will also be used as the control. These plots will be divided in three subplots planted with bok choy, cucumber, or bell pepper, and further divided in sub-subplots, with one fertilized using only composted poultry manure and the other managed with an \"integrated\" approach combining a cover crop N credit, lower poultry manure rates and fertigation with low-P organic fertilizers to provide the balance of N to meet crop demand. Each treatment combination will bereplicated four times using a block design, for a total of 120 plots. Experimental plots will be established on roughly 1.5 acres of certified organic land at Citra, FL. Cover crops will be seeded in early July and terminated in late August, using a flail mower and a disk to incorporate residues into the soil, and vegetable crops will be planted within a 5-day window 7-10 days after cover crop termination. Fertilization will be made according to UF-IFAS recommendations; for the manure system, all of the N will be added at planting with composted poultry manure, assuming 50% availability of total N in the manure. For the integrated nutrient management approach, we will add the equivalent of 25 kg P ha-1through composted manure, assume that 20% of cover crop N inputs will be made available to vegetable crops, and add the balance of the N recommendation with fertigation using low-P products. OMRI-certified nutrient sources will be added if required based on soil tests, and OMRI-certified pesticides will be used ifneeded for foliar disease and pest management.Vegetable crops will be harvested in mid-October (bokchoy), between mid-October and mid-November (cucumber), and between early November and mid-December (bell pepper).Methods for objective 1Vegetable yields and aboveground biomass will be measured using 15 plants per plot located in the central bedof each plot. Asubsample will be used from each plot to quantify crop quality and nutrient concentration (N, P, K, other macro- and micronutrients). Cover crop biomass will be sampled at termination using two random 0.5 m quadratsin each plot andsorted by species. For both cover crops and vegetables,total C and N will be determined by combustion, including15N concentration. Soils will be collected regularly to measure soil extractable N (with 2M KCl), N mineralization, and N cycling gene abundance. Twenty cores per plot will be collected from the top 20 cm of soil in thesame central bed used for vegetable yield measurements and homogenized before analyses. We will measure N cycling gene abundance threetimes per year for bok choy and pepper plots only, and extractable N and N mineralization six times per year for all vegetables. Soil for N cycling genes will be stored at -80°C until DNA extraction and qPCR analysis for N cycling pathways: N2-fixation (dinitrogen reductase, nifH), nitrification (archaeal and bacterial ammonia monooxygenase, amoA), and denitrification (nitrous oxide reductase, nosZ).We will collect additional soil samples after cover crop termination to quantify the15Nsignature of the extractable pool, combine with cover crop and vegetable crop15Nsignature, and use a standard isotopic mixing model to quantify N inputs from legume cover crops using the natural abundance of15Ntechnique.Methods for objective 2We willconduct three measurements of SPAD, petiole sap nutrient content and leaftissue analysis for each crop at critical growth stages during the growing season. Disease and pest damage (includingincidence and severity) will be assessed for major problems. Both marketable and unmarketable yields will be measured for each crop, including cullfruit numbers. We will assess quality attributes of harvested vegetables (e.g., drymatter content, total soluble solids, ascorbic acid content).Asubsample from soilscollected for N cycling measurements will be used to measure plant-parasitic nematodes before and after cover crops, and after the harvest of each vegetable. Nematodes will be extracted using the sucrose-centrifugation technique andthen identified and quantified based on morphology using a microscope. Root damage by root-knot nematodes will be assessed by evaluatingroot galling after harvest in all vegetables.A subsample of each DNA extraction collected for functional geneabundances will be preserved at -80°C until the end of the experiment. Following the analysis ofqPCR data, we will select two dates to be analyzed by high-throughput ampliconsequencing to determine microbial community composition. Extracted DNA will be sent to an outside facility for high throughput ampliconsequencing utilizing the Illumina MiSeq platform.A subsample from the soils collected for N cycling willbe analyzed for hexanol-extractable P and other soil health indicators, according to NRCS guidelines:permanganate-oxidizable C and mineralizable C during a 4-day incubation, and autoclaved citrate extractable protein. Soil total C and N will be measured by combustionafter cover crop termination.Soils collected before and after cover cropswill be analyzed by an external laboratory for macro- and micronutrients, soil pH, and cation exchange capacity.Data will be compiled upon the completion of the trial and subsequent lab processing. ANOVAs following a split-split-plot design will be used to determinethe effects of the different treatments on crop health, yield and vegetable quality,

N cycling indicators, plant-parasiticnematodes, and soil health indicators. Correlation analyses will be used to link the different response variables. High-throughput sequencing datawill be analyzed using QIIME 2and multivariate statistical approaches will be used todescribe soil communities. Additionalmultivariate analyses andvisualization toolswill be used to determine the effects of the different treatmentson system performance as a whole.Methods for objective 3We will hold one field day during the vegetable crop growing season of the secondyear to present results and provide a tour of the experiment to participants. We will provide a pre-test survey of participants\' knowledgeand perceptions about how to best use cover crops for N benefits in organic vegetable production,using Qualtrics (paper versions will be available). We will assess knowledge gain at the end of the field day and 12 months after the field day using post-event surveys, to determine the extentof adoption of new practices and level of knowledge transfer achieved.We will produce different extension documents (e.g., factsheets), after all the data have been analyzed, and a short presentation summarizing the main research resultswill be shared during other events.Two short videos summarizing key research outcomes will be created and posted on social media: one focusing on N cycling, the other on broader implications.We will share our research results with extension agents and other professionals during a professional development workshop that will be developed after the results and their implications have been fully analyzed. We will evaluate thetransfer of knowledge from these sessions using similar tools as for the field day (pre and postassessments), focusing on technical aspects of the research.Finally,PDs with formal teaching assignments will share research outcomes from this proposal with students in aformal classroom setting. Given that many students have professional work aspirations (e.g., crop consultants), sharing key conclusions with them will further disseminate this research\'s results. Progress 09/01/23 to 08/31/24 Outputs Target Audience:The target audience has not changed and continues to be mainly organic growers and professionals of Florida and the Southeast US. In addition, undergraduate and graduate students and other members of the academic community are also a target audience of this project. Changes/Problems:The former postdoctoral fellow (now at USDA-ARS in NE) who led data analysis and writing for several datasets, went on parental leave for several months during the reporting period, which delayed data analysis and manuscript writing. As she is back full-timeas of August 2024, progress should return to a more rapid pace for the end of the award period. What opportunities for training and professional development has the project provided?The postdoctoral fellow (Dr. Ariel Freidenreich) originally recruited to lead this project has been atthe USDA-ARS in Nebraska for this reporting period. Despite the change in position and going on parental leave from April until August (part-time leave for the last few months), she has continued tomanage data from the project in her new position, as time allows. Gabriel Maltais-Landry (PD) had a MS student helping with the greenhouse study as part of her thesis.Zane Grabau (co-PDworking on nematodes) has a PhD student that is working on this project as part of her PhD dissertation project. Xin Zhao (co-PDworking on crop quality and weeds) has recruited twopart-time postdoctoral associates to work on data analysis and writing for this project. The other co-PDs have relied more on research technicians, and all PDs have involved undergraduate research assistants whenever possible. How have the results been disseminated to communities of interest?PD Maltais-Landry shared key results on nutrient management during his CCA talk while the talks given by the former postdoctoral fellow at the Tri-Societies conference and the graduate student at the Society of Nematologists were well attended, allowing tosharethose results with the US research community. What do you plan to do during the next reporting period to accomplish the goals?SO1: As all sample collection and processing activities are complete, remaining tasks are to fully validate data, complete data visualization and analyses, andwrite scientific manuscripts. The manuscript on 15N and N cycling should be completed and submitted by the end of the award period (2/2025) whereas the greenhouse study might only be submitted after the award period. SO2: As all sample collection and processing activities are complete, the main tasks remaining are data analysis and writing. Two manuscripts (one on cover crop and weed biomass, and one on cash crop yieldand crop quality) are currently being written, and they should be submitted to HortScience as companion papers by the end of 2024. Most data analysis is completed for the nematodes dataset and manuscript writing is ongoing; this manuscript should be submitted by the end of the award period. The other two datasets (soil health indicators and non-nitrogen nutrients) should have data analyses completed by the end of the award period, although manuscript submission will occur after the award period is over. SO3: Upcoming talks at scientific conferences will continue to disseminate research result to the scientific community. We are planning to hold a virtual field day toshare the main outcomes with key stakeholders, and we will follow-up with more traditional written extension documents - this has been delayed by the necessary data analysis of the data, which has taken more time than expected. PDMaltais-Landry will continue to share key results at CCA meetings and other such venues. Impacts What was accomplished under these goals? As all field activities and sample collection activities were completed inthe last reporting period, the main activities for this reporting period consisted in the completion of sample processing, and ongoing work on data analysisand writing. Accomplishments related to each specific objective are: SO1: With all samples processed for 15N and other N cycling measurements, we validatedthe data for both years and we started data analyses. At this stage, data for both years are consistent in terms of the fraction of 15Nrecovered from cover cropsin cash crops (i.e., less than 20% of the cover crop N appears to be recovered by cash crops) andmore refined data analyses are ongoing. We have also completed sample processing for a

companion greenhouse study with 15N residues using bok choy as a response crop, and data analysis has started for this dataset as well. SO2: All cover crop biomass, weed biomass, and cash crops yield data were compiled, in addition to crop quality (e.g., soluble solids content, total titrable acidity, etc.). Data analyses were completed, and we started manuscript writing for this dataset; wechose to split the data in two manuscripts as it was too much for a single manuscript. These manuscripts should be submitted as companion papers to HortScience, by the end of 2024. All samples were processed for soil nematodes, and data analysis was completed; aconference presentation was made, and the manuscript is currently being written. All qPCR analyses have been completed, and amplicon sequencing analyses were recently completed, with data analysis using bioinformatics tools ongoing. Finally, all soil health indicators (POXC, ACE protein, mineralizable C) were quantified from air-dried samples collected at the same frequency as nematodes and microbial communities. SO3: We have shared the main nutrient management outcomes during a presentation at the Certified Crop Advisor meeting/training held virtually in June at UF. Two presentations were given at scientific conferences: one at the Society of Nematologists (annual meeting in August 2024)and one at theTri-Societies (annual meeting in Oct.-Nov. 2023). Publications Type: Conference Papers and Presentations Status: Accepted Year Published: 2024 Citation: S. Budhathoki, Z.J. Grabau, G. Maltais-Landry. Effects of cover cropping systems on soil nematode community composition in organic vegetable production. Conference presentation at the Society of Nematologists Annual Meeting. August 2024. Park City, UT. Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: Freidenreich, A.P, and Maltais-Landry, G. 2023. Evaluating How Cover Crops of Varying Diversity and Two Fertilization Approaches Affect Soil Nutrient Cycling and Soil Health Indicators in Organic Vegetable Systems of Florida. Conference presentation at the ASA-CSSA-SSSA Annual Meeting. Oct.-Nov. 2023. St. Louis, MO. Progress 09/01/22 to 08/31/23 Outputs Target Audience:The target audience has not changed and continues to be mainly organic growers and professionals of Florida and the Southeast US. In addition, undergraduate and graduate students and other members of the academic community are also a target audience of this project. Changes/Problems:We had much better cover crop and cash crop growth in 2022, but we had a limited number of peppers available in 2022 due to delivery issues that damaged \>75% of the pepper transplants we ordered from the greenhouse. We still got good growth from the peppers planted, but the lower number of plants made things more complicated. We had two hurricanes somewhat hit the station in 2022, but luckily the eye and heavy winds dodged the station for the most part, so as far as we know there was no major damage that occurred to the experiment. As we got low recovery of 15N in cash crops for both years, we setup a relatively simple greenhouse experiment using only sunn hemp 15N residues and bok choy, using a factorial design with different rates of residues added crossed with different levels of certified organic N fertilizer. We were very careful to minimize any leaching and other N losses, hence we are hopeful that this will allow us to better quantify 15N transfer to cash crops and soils, and complement our field work, by providing a \"ceiling\" for the potential of cover crop N to be transferred to cash crops in these systems. What opportunities for training and professional development has the project provided?The postdoctoral fellow recruited to lead this project has completed half of her second year in February 2023, before moving on to a new position at the USDA-ARS in Nebraska. She has continued to provide leadership and has worked with three undergraduate students and another technician (that became a graduate student in fall 2022) during field work, and she has continued to manage data from the project in her new position, as time allows. With the departure of the postdoctoral fellow, this has opened opportunities for undergraduates to become more independent and take more ownership in some aspects of the project (e.g., the soil health indicator measurements are driven by an undergraduate intern). Zane Grabau (co-PI working on nematodes) has a PhD student that is working on this project as part of her PhD dissertation project. Xin Zhao (co-PI working on crop quality and weeds) has recruited a part-time postdoctoral associate and two part-time undergraduate students to work on this project. The other co-PIs have relied more on research technicians, and they have involved undergraduate research assistants whenever possible. Postdocs, students, and technicians have been invited to speak at the field day, to develop their capacity to present to a lay audience, and the postdoc has presented at a scientific conference. How have the results been disseminated to communities of interest?The field day of 9/21/2023 was attended by over 50 people, over half of which were growers. The talk given by the postdoctoral fellow at the Tri-Societies conference was well attended and shared those results with the US research community focusing on organic systems. What do you plan to do during the next reporting period to accomplish the goals?SO1: As all field activities are completed, remaining tasks are to fully validate data collected so far and conduct potential reruns (e.g., for soil N analyses) if needed. We will wrap up sample analysis for the greenhouse experiment we conducted and double-check 15N models used to refine our estimates of 15N transfer from cover crops to cash crops and soils. The next steps will be to conduct statistical analyses to interpret data and write scientific manuscripts. SO2: Crop quality analyses have been completed, and good progress has been made on soil measurements. Mineralizable C remains to be quantified for soil health indicators, a few dates of counts remain for nematodes, and a few genes for qPCR and amplicon sequencing remain for microbes. The next steps will be to conduct statistical analyses to interpret data and write scientific manuscripts. SO3: Upcoming talks at scientific conferences will continue to disseminate research result to the scientific community. The planned virtual field day will also help

share the main outcomes with key stakeholders, and we will follow-up with more traditional written extension documents, although a more thorough analysis of results is necessary prior to extension products being created. PI Maltais-Landry is also planning to present the key results of this work on nutrient management in organic vegetables at an upcoming Certified Crop Advisor meeting, most likely in Spring 2024. Impacts What was accomplished under these goals? The second year of the experiment was completed in December 2022, with the final soil samples taken early in January 2023. This second year consisted of a cover cropping phase in summer 2022 followed by a cash cropping phase in fall 2022. The same plots (120 in total) were maintained and studied over the course of the project, with 3 cash crops, 5 cover crops, and 2 nutrient management approaches, in a fully factorial design. Accomplishments related to each specific objective are: SO1: Following cover cropping termination in Aug. and Sept. 2022, nutrient management treatments (all preplant vs. integrated, i.e., preplant and fertigation) were applied and 15N-labeled cover crop residues were added to trace N from residues to fall cash crops. Fall cash crops were planted and harvested. 15N was measured in soils and cash crop biomass (yield and aboveground non-marketable biomass), while N concentrations were measured in cover crops and all cash crops. Soil inorganic N was measured throughout the year, including incubations to determine N release from organic amendments and cover crop residues. Year 2 data confirmed several patterns that were observed in year 1, with the main exception being that a better optimization of the \"integrated\" nutrient management approach resulted in no/lower yield gaps relative to the \"preplant\" nutrient management approach. Year 2 of 15N tracer recovery from cover crop residues in cash crops confirmed year 1 results, in that less than 20% of the cover crop N appears to be recovered by cash crops (often much less than that) although more refined data analyses are needed to reduce the uncertainty on these estimates. We have also conducted a greenhouse study with 15N residues using bok choy as a response crop to minimize N losses and determine what might be the \"ceiling\" for 15N recovery when conditions are optimal. SO2: Cash crops were sampled during the growing season for several properties (SPAD, plant height, stem diameter) and marketable biomass was sampled for crop quality (leaves for bok choy, fruits for zucchini and pepper). Crop quality samples preserved at -20C were analyzed for soluble solids content, titrable acidity, the ratio between the two, ascorbic acid content, total phenolics content, and total antioxidant capacity. Preliminary analyses of both years highlight complex interactions among treatments that vary based on cash crop and year - additional statistical analyses are underway to better disentangle the key patterns in crop quality. Weed assessments were also conducted for all crops; nutsedge and wild mustard dominated the weed community. All cover crops provided benefits in terms of nutsedge management for bok choy, with benefits of some cover crops for peppers, and no cover crop benefits for weeds in zucchinis. Soil samples before cover crops, after cover crop termination, and after fall cash crop harvest have been collected for both nematodes and microbial communities. Samples for nematodes have been extracted for all dates and nematode communities are currently being measured. Fall and spring cash crops were also assessed for root damage due to root-knot nematodes. So far, limited differences among treatments have been observed, but a more thorough analysis will be conducted once all the samples have been counted for nematodes. For microbial communities, DNA was extracted for all samples of both years. qPCR analyses have been run for all six genes in year 1 and four out of six genes in year 2. Once the data is analyzed for all genes of year 2, a subset of samples from year 2 will be submitted for amplicon sequencing. Finally, soil health indicators were quantified from air-dried samples collected at the same frequency as nematodes and microbial communities. Permanganate-oxidizable carbon and soil protein have been quantified so far for all samples, while mineralizable C will be quanitifed by the end of 2023. SO3: We have completed a succesful field day on Sept. 21, 2022 that covered the key outcomes observed so far from this experiment. We are hopefullly going to conduct a virtual field day follow-up in early 2024 to present the conclusions of the work. A presentation was submitted to the Tri-Societies meeting in Baltimore (Nov. 2022), and an abstract was submitted for the same meeting in St-Louis (Oct.-Nov. 2023). Publications **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:The target audience has not changed and continues to be mainly organic growers and professionals of Florida and the Southeast US. Inaddition, undergraduate and graduate students and other members of the academic community are also a target audience of this project. Changes/Problems:Pepper growth was relatively poor in 2021, which was likely due to greater weed pressure and lower SOM in the field selected for this crop, as zucchini and bok choy performed much better. As we rotate crops for fall 2022, peppers and bok choy will be planted in the better fields, and zucchini will be moved to the field previously cropped with pepper. Given its greater weed competitiveness relative to pepper and the expected benefit of multiple organic amendment applications on SOM, we are confident that zucchini will perform better than pepper in that field. Cover crop growth improved in 2022 relative to 2021, but the production of 15N-labeled residues for millet was poor. As a result, we will have to reduce the supplementation of 15N-millet residues in these treatments to ensure all plots with millet planted receive15N-labeled residues. This should not impact our capacity to quantify the N transfer from cover crops to cash crops. We have thus far obtained relatively low recovery of 15N in cash crops, which could be driven by methodological challenges. We have revised our protocols for this season and will hopefully reduce potential losses of 15N, allowing to increase the recovery of cover crop N in the subsequent cash crops. What opportunities for training and professional development has the project provided?The postdoctoral fellow

recruited to lead this project has completed her first year in June 2022. She continues to provide leadership and has trained two undergraduate students (including a student intern from Zamorano University) and another technician. Zane Grabau (co-PI working on nematodes) has recruited a PhD student that is working on this project as part of her PhD dissertation project. Xin Zhao (co-PI working on crop quality and weeds) has recruited a part-time postdoctoral associate and three part-time undergraduate students to work on this project. The other co-PIs have relied more on research technicians. Postdocs, students, and technicians have been invited to speak at the field day, to develop their capacity to present to a lay audience. How have the results been disseminated to communities of interest?None at this stage, but the first round of dissemination will occur early in the next reporting period, during the Sept. 21, 2022 field day. Other extension activities and products will follow once data have been collected and results interpreted. What do you plan to do during the next reporting period to accomplish the goals?SO1: Complete the second year of the experiment, consisting in the termination of cover crops and the growth of fall cash crops - we expect all field activities will be completed by December 2022. During this period, we will conduct the same activities as we conducted during the fall of 2021, i.e., addition of labeled 15N residues and nutrient management treatments, followed by crop sampling at harvest for 15N and N concentrations. We will also collect soils and perform incubations to determine N release from residues and amendments. Finally, all samples will be processed in the laboratory before formal statistical analysis and writing. SO2: We will follow up a similar timeline of field activities and sampling as SO1. Soil health indicators, nematodes, and microbes will be measured from soils collected at cover crop termination and after cash crop harvest, whereas crop quality measurements will be taken again from harvested biomass. Sample processing(included preserved samples from Fall 2021) will be completed, before formal statistical analysis and writing. SO3: Organization for our Sept. 21 field day is underway, with 20 participants registered (and several weeks to go prior to the event per se). The presentation of research results at the Tri-Societies meeting will allow to share results with the scientific community. Extension products will be written in the second half of the next reporting period, as data interpretation becomes clearer. **Impacts** What was accomplished under these goals? The first year of the experiment was completed in May 2022, when the second year of the project started. This second year consists of a cover cropping phase in summer 2022 followed by a cash cropping phase in fall 2022. The same plots (120 in total) were maintained and studied over the course of the project, with 3 cash crops, 5 cover crops, and 2 nutrient management approaches, in a fully factorial design. Accomplishments related to each specific objective are: SO1: Following cover cropping termination in Aug. and Sept. 2022, nutrient management treatments (all preplant vs. preplant and fertigation) were applied and 15N-labeled cover crop residues were added to trace N from residues to fall cash crops. Fall cash crops were planted and harvested, followed by a winter rye cover crop, a spring chard cash crop, and finally a repeat of the same cover crop treatments that were established in summer of 2021. 15N was measured in soils and cash crop biomass (yield and aboveground non-marketable biomass), while N concentrations were measured in cover crops and all cash crops. Soil inorganic N was measured throughout the year, including incubations to determine N release from organic amendments and cover crop residues. Preliminary results suggest that cover crop biomass production was largest in the sunn hemp monoculture and the biculture of sunn hemp and sorghum sudangrass. There was greater soil inorganic N and yields when all the fertility was provided before planting (as opposed to preplant and fertigation), whereas cover crops did not have a large impact on those. The recovery of 15N tracer from cover crop residues in cash crops was less than 10%. SO2: Cash crops were sampled during the growing season for several properties (SPAD, plant height) and marketable biomass was sampled for crop quality (leaves for bok choy, fruits for zucchini and pepper). Crop quality samples are being preserved at -20C for future analyses (e.g., ascorbic acid, soluble solids). Weed assessments were also conducted for all crops; nutsedge and wild mustard dominated the weed community. Soil samples before cover crops, after cover crop termination, and after fall cash crop harvest have been collected for both nematodes and microbial communities. Samples for nematodes have been extracted and nematode communities are currently being measured. Fall and spring cash crops were also assessed for root damage due to root-knot nematodes. For microbial communities, DNA was extracted for pepper and bok choy in all plots and for all sampling points. Bacterial qPCR has been run, while total archaea qPCR is ongoing. Finally, soil health indicators were quantified from air-dried samples collected at the same frequency as nematodes and microbial communities. Permanganate-oxidizable carbon and soil protein have been quantified so far for year 1 samples. SO3: Extension and outreach products have not been published yet, but a field day is being organized on Sept. 21, 2022, which will cover the key outcomes observed so far from this experiment. An abstract was submitted to the Tri-Societies meeting in Baltimore (Nov. 2022). **Publications** Progress 09/01/20 to 08/31/21 Outputs Target Audience: Organic growers and professionals of Florida and the Southeast US; undergraduate and graduate students. Changes/Problems: COVID-19 constraints forced us to delay the start of the experiment by one year, to allow for research restrictions to be lifted, especially regarding hiring. Given the current rate of progress, all field activities should be completed by December 2022; lab analyses, data analysis/processing and extension/outreach activities should be completed in early 2023. We also improved our experimental design. The original design consisted of cover crop treatments as the main plots, cash crops as the subplot, and nutrient management treatments as the sub-subplot. Upon further discussion with

stakeholders, we decided to have three different experiments (located in close proximity), i.e., one per cash crop. Within these, cover crop treatments are the main plots and nutrient management treatments are the subplots, allowing us to plant and terminate cover crops at different times and better synchronize cover crop termination with cash crop planting for different cash crops. This will ensure that growing conditions and management practices are more consistent with what farmers do in the area, increasing the potential impact of our work. What opportunities for training and professional development has the project provided? A postdoctoral fellow has been recruited and is mentored, taking an increasingly important role in the coordination of the project. An undergraduate student is also working as a part of this project and being trained accordingly. 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? SO1: We will add 15N-labeled residues and trace 15N from cover crop residues in soil pools and cash crops; we will plant and harvest cash crops and measure yields and nitrogen fluxes; and we will quantify N cycling through soil sampling conducted before, during and after the cash crop growing season. After the completion of cash crop harvest (December 2021), a winter cover crop will be planted, followed by a spring cash crops; yield and N cycling will be quantified during both cropping phases. In June 2022, we will establish summer cover crop treatments again, including the production of 15N-labeled residues if needed. In addition, samples will be processed in the laboratory. SO2: In the plots established for SO1, we will quantify soil health indicators, nematodes, and microbes in the same soil samples that are collected for N cycling; these soil samples will also be analyzed in the laboratory. Crop quality will be evaluated for each cash crop, including laboratory analyses when needed. SO3: Starting in Spring 2022, we will plan our first field day, including the decision to do a virtual or in-person field day. Preliminary research results will also be shared, including the submission of an abstract to the SSSA conference to be held in Fall 2022. Impacts What was accomplished under these goals? During this first year of the project, we decided to delay the start of the experimental phase to summer 2021 to allow for COVID-19 restrictions (travel, hiring, number of people allowed per lab space) to be lifted. This also allowed the team to plan the experiment adequately and hire the postdoctoral fellow (who started in June 2021) and supporting personnel. We started the project in June 2021 by taking initial soil samples, planting cover crops, and producing 15N-labeled cover crop residues. SO1: We planted cover crops in three fields, one per cash crop (pepper, squash, bok choy), staggering plantings by two weeks from mid-June onwards. Cover crop termination and cash crop planting will also be staggered by two weeks, with the first termination completed in late August. Cash crop planting willstartin early September 2021 with a 2-week staggering approach. In these fields, we collected initial soil samples for N cycling measurements (N mineralization, soil inorganic N). In parallel, we grew cover crop residues with a 15N label, and harvested this biomass that will be added to the main experiment to generate a pulse of 15N that can be traced in soil pools and cash crops. SO2: In the plots established for SO1, we collected initial soil samples for soil health indicators, nematodes, and microbes. Another set of samples will be collected prior to the planting of each cash crop. SO3: Given the early stage of the experimental work, no extension/outreach activities have occurred yet. Publications

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Breeding Corn to Enable Organic Seed Production

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Project No.	ILLW-2020-02117
Agency	NIFA ILLW\
Project Type	OTHER GRANTS
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Investigator(s)	Scott, P.; Lubberstedt, TH, .; Bohn, MA, .; Linares, AN, M.
Performing Institution	AGRICULTURAL RESEARCH SERVICE, 1815 N University, Peoria, ILLINOIS 61604

NON-TECHNICAL SUMMARY

This project builds on the germplasm, methods and technologies developed in three previous OREI projects to achieve the objective of enabling seed companies to use organic management to produce corn seed sold to organic farmers. We will do this by developing 3-way hybrids that are better-suited to organic seed production than the single-cross hybrids currently marketed by most companies. These hybrids will carry traits desired by organic producers such as high levels of the essential nutrient methioinine and the ability to exclude GMO pollen using the Ga1 pollen exlusion system. We propose to develop a new rapid cycling breeding method that combines the contemporary methods of genomic slection and doubled haploid breeding with an organic- friendly breakthrough techonology called Spontaneous Haploid Genome Doubling. This approach will allow us to produce new varieties in about one fourth the time required by current methods. A key outreach activity will be two Organic Corn Breeding Boot Camps held at our winter nursery site in Puerto Rico and attended by midwest farmer cooperators, project investigators, and student interns from the Univeristy of Puerto Rico. Attendees will work togther to produce seed and plan on-farm trials for the following summer. Interns will travel to the farmers\' locations in the summer to assist with the trials. The boot camp will provide a novel opportunity for farmers and breeders to cooperate in the process of variety development and testing.

OBJECTIVES

Corn is the second largest organic grain/seed crop in the U.S. behind wheat (Agricultural Marketing Research Center, 2018). While several seed companies sell seed that can be used in certified organic systems, essentially none of the varieties available were developed specifically for organic production systems and very few have even been evaluated in organic production environments. Further, only a small proportion of the seed sold to organic farmers is produced using certified organic practices. The goal of this work is to expand organic production by developing new varieties that are suited to seed production using certified organic practices and have characteristics desired by organic producers and to do this rapidly with a novel rapid cycling plant breeding method.

APPROACH

Rapid cycling OREI breeding pipelineRapid cycle breeding will be done by a novel combination of Genomic Selection and Doubled Haploid breeding, taking advantage of SHGD to allow recombination and seed increase to occur in the same generation. We will implement a rapid cycling breeding strategy for rapid recurrent genomic selection for DH line development and population improvement under organic conditions, starting with germplasm developed by project cooperators and carrying traits desired by organic producers including high methionine concentration and the ability to exclude foreign pollen. We will evaluate DH lines and their testcrosses under organic conditions in Iowa, Illinois, and Puerto Rico. Genotyping will be outsourced to a service provider that offers competitive technology and pricing. Finally, we will incorporate SHGD for efficient and colchicine-free DH line development.GermplasmWe will simultaneously improve two populations applying a reciprocal recurrent selection approach in which the products of the female pipeline will be used as testers for the male pipeline and vice versa. The two starting populations will be constructed from different and complementaryheterotic pools. One population will be improved as the seed parent (\"female\"), whereas the second population will serve as the pollen parent (\"male\"). The female heterotic pool will be derived from the Iowa Stiff Stalk Synthetic population combined with high methionine germplasm. We will introgress the pollen exclusion gene Ga1 and the major SHGD QTL (inbred lines carrying these genes are available) and further cross the high-methionine population with GEM and exPVP derived inbreds to broaden the genetic basis for agronomic performance and insect resistance. The goal will be to fix Ga1 and SHGD in the female population quickly and to provide sufficient genetic diversity for a sustained long term selection response. The male heterotic group will be based on population BS39 which was selected from exotic Tusón germplasm and adapted to the U.S. Corn belt. BS39 derived DH lines carrying the major SHGD QTL are already available.Improvement CyclesThe population improvement cycle will consist of two generations, carried out in the winter and summer nurseries of the one year: (1) haploid induction in breeding population, followed by (2) genotyping, selection and combination of most promising fertile haploids based on GEBVs, as well as self-pollination for DH line development. Crosses between fertile haploids will constitute the improved population which will be induced to continue the population improvement cycle.The product development cycle will be based on the selected self-pollinated fertile haploid (D0) plants. The resulting D1 lines will be self-pollinated for seed multiplication and crossed with a tester from the other pipeline for testcross seed production. Resulting hybrids will be evaluated under organic conditions for yield and yield component traits, and respective phenotypic and genotypic data will be used to update the training model for genomic selection.Genomic SelectionOur experience with variety trials conducted in organic on-farm experiments suggests that organic testing environments tend to have more experimental variation than non-organic environments. We will account for this difference by testing with greater replication than is normally used. Extending our testing efforts to a large number of environments per year (N \> 10 environments) will accumulate the data we need to estimate and model Genotype × Environment interactions.We will develop genomic models to predict DH per se performance and performance in single and three-way hybrids. For our rapid cycling OREI breeding pipeline, we will adapt the general and subpopulation-specific additive ridge regression best linear unbiased prediction approach (GAS-RRBLUP). The seed parent will be a single cross hybrid (Female1 × Female2) developed from two inbred lines obtained from the female population.For this project, three-way hybrids come in two \"flavors\" with consequences for the applied genomic prediction protocol. Approach 1 - Female1 and Female 2 are closely related and both combine well with Male1. Approach 2 - Female1 and Female2 form a single-cross hybrid that maximizes intrapool heterosis and combines well with Male1 to produce a highly productive three-way hybrid. We will simulate traits with additive effects and additive and dominance effects, assuming different heritabilities (0.2, 0.5 or 0.9), and number of loci (3, 10, 25, or 75). Each genetic architecture will be simulated for multiple environments using the R package simplePHENOTYPES (https://bitbucket.org/fernandessb/simplephenotypes). We will test GS models for each approach (i.e., \"modified single cross hybrid\" vs \"three-way hybrid\") using available SNP marker information applying GAS-RRBLUP. Prediction accuracies for each genetic architecture will be conducted using a 5-fold cross-validation scheme. Our GS models will be used to select haploids for product development and population improvement. For population improvement selected and fertile haploids with a predetermined minimum genetic distance will be crossed to build F1 hybrids. To rapidly fix the pollen exclusion and spontaneous haploid genome doubling trait in our breeding populations, each F1 hybrid will be homozygous for the Ga1 pollen excluding locus and the major SHGD QTL. A balanced bulk of F1 hybrid seed will form the next improved cycle of the breeding populations.Doubled HaploidsThis project will require selection of millions of haploid kernels, requiring a great deal of manual labor. In order to increase the efficiency of this process, we will attempt to use single kernel evaluation by near-infrared reflectance spectroscopy (NIRS) using the skNIRS sorter for automated haploid selection. In addition to haploid selection, PI Scott will establish a calibration to identify haploids with high methionine content. Calibrations that predict methionine concentration in bulk grain exist, so it should be possible to develop a single kernel calibration.Haploid kernels selected based on NIRS will next be grown in organic nurseries to select the most vigorous haploid plants. We will induce haploid lines from existing BS39-derived inbred lines. Currently, more than 200 BS39 lines carrying SHGD are available, and have been genotyped. We will induce haploids for those 200 lines, each of which will be genetically uniform haploid lines and isogenic to the

respective diploid BS39 lines. Those isogenic line pairs will be planted side-by-side in replicated trials in organic nurseries in Iowa and Illinois, to capture various agronomic traits, including seedling vigor and survival rate, plant height, etc. Since those lines have been genotyped, it will be possible to identify genome regions contributing to seedling vigor and overall inbred line performance both at the haploid and diploid level, and to incorporate these information in GS models.We will evaluate whether it is possible to reliably obtain 3 generations per year in Puerto Rico. The most important genotype to be consistently used in population improvement cycles is a haploid inducer. At the DH Facility at ISU led by co-PI Lubberstedt, more than 180 haploid inducers i have been developed, which will be evaluated for adaptation to different seasons in Puerto Rico. Primarily, adaptation traits such as resistance to local diseases and insects, tolerance to abiotic stress factors, lodging tolerance, ability to shed pollen and set seed will be monitored during the first two years of the project. The best inducer will be used for small scale haploid induction trials to produce haploids from a limited number of donor genotypes in a pilot 3-generation per year cycle, to establish protocols for working with haploid plants. If successful, larger-scale haploid inductions will be initiated from year 4 on. Progress 09/01/22 to 08/31/23 Outputs Target Audience: Nothing Reported Changes/Problems:Our main challenge is that the performance of our varieties is in most cases well below that of commercial varieties. We will continue to incorporate the best germplasm available into our breeding program. Our rapid cycling approach should allow us to improve our varieties faster than the commercial corn breeding programs can improve theirs. We should eventually catch up to them, but until we have run a few breeding cycles we will not knowhow long this will take. What opportunities for training and professional development has the project provided?We held our first Corn Breeding Boot camp in conjunction with our organic winter nursery pollination in late January in Lajas Puerto Rico. The grant funded three organic corn farmers from the Midwest to travel to Puerto Rico and work side by side with student interns from from the University of Puerto Rico and the investigators on the grant. In addition to the hands-on work experience, discussion sessions provide context that ties the field work to the larger objectives of the project and to the scientific theory behind the work. These sessions also allowed for sharing of ideas between students, farmers and scientists. Two student interns from Puerto Rico traveled to the Midwest during the following summer and assist with the field work at the university locations. They also visited the farms of the boot camp participants to learn about organic corn production in the Midwest. The boot camp provides a hands-on learning and information sharing opportunity for farmers, students and scientists interested in organic corn production. Research technicians Luisa Flores and Leidy Sarmiento managed/lead the Organic Winter Nursery performed from December 2022 to April 2023 and trained four undergraduate students from the University if Puerto Rico, Mayaguez (Elian Pabón, Marielis Santiago, Yamilette Rosado, Krinten Otero), in technical aspects of the field work required for the project. Two students from the previous season were retained (Arialie Figueroa, Thalia Ramos) to work in winter nursery activities. Also, Yamilette Rosado (Bohn\'s Research Program) and Thalia Ramos (Lubberstedt\'s Research program - ISU) spent +8 weeks performing an internship focused on corn breeding and nursery methods as part of the boot camp activities described above. Some demographic data of the winter nursery student participants, 64% has been females and 36% males; most students belong to the Agroenvironmental Sciences Department (Agronomy and Crop Protection), other departments impacted have been Ag Economics, General Agriculture, and Biology.; 100% has been undergraduates. Their GPA fluctuates from 2.60 to 3.83; 40% are in the 6thyear of their studies, 20% in their 5th; 20% in their 4thyear, and 20% in their 3rd. All of them recognize themselves as Hispanic or Latino. 60% of the participants\' students are first-generation university students in their household. 80% consider themselves fluent in writing and talking in English and Spanish, while 20% consider themselves fluent in writing in English but not fluent in talking in English. 36% of the participants have graduated from the university, just 18% enrolled in graduate school in Soils and Business; 10% is working in RiceTec Inc. a winter nursery division of Hybrid Rice Seeds, 64% still performing undergrad studies. 55% of the participants in the winter nursery activities had the opportunity to participate in the summer internship experiences with the collaborators and PI of the grant. Ph.D students Shelly Kinney (Iowa State University) and Chris Mujjabi (University of Illinois - Urbana Champain) were supported by the project carried out research on their dissertations that is aligned with project objectives. Student hourly worker Hannah Clubb was trained in corn breeding methods while supporting project research. Hannah attended the 2023 National Association of Plant Breeders annual meeting in Greenville South Carolina as a Borlaug Scholar. How have the results been disseminated to communities of interest?Paul Scott gave a presentation at the University of Missouri, Columbia entitled \"Breeding Corn for Organic Production Systems\" November 14, 2022. Press release by ARS News Service, \"Scientists ratchet up key amino acid in corn\" September 28, 2023, https://content.govdelivery.com/accounts/USDAARS/bulletins/372a2e6 Paul Scott discussed this project at the Iowa Organic Association Field day, September 7, 2023, Wesley Iowa Paul Scott, Uschi Frei and Elizabeth Bovenmyerdiscussed this project at the Shriver farm field day, August 1, 2023, Jefferson, Iowa Hannah Clubb (Iowa State University undergraduate student) was interviewed by Seed World (https://www.seedworld.com/hannah-clubb-on-going-to-school-while-battling-cancer/). Park, Tae-Chun; Kinney, Shelly; Lauter, Adrienne N; Scott, Paul M,Aboobucker, Siddique I; Frei, Ursula K; Lübberstedt, Thomas, 2023, Application of DH technology and molecular markers to combine multiple major genes for improving corn quality,

Poster #134 at the 65th annual Maize Genetics Conference, St. Louis Mo. Bapat, Amruta R; Moran Lauter, Adrienne N; Hufford, Matthew B; Boerman, Nicholas A; Scott, Paul M, 2023,The Ga1 locus of the genus Zea is associated with genome structures derived from multiple, independent non-homologous recombination events, Poster #249 at the 65th annual Maize Genetics Conference, St. Louis Mo. What do you plan to do during the next reporting period to accomplish the goals?In the next year we will begin testing genomic prediction models and intermate lines to develop the female population for the rapid cycle breeding program. We will continue to carry out evaluation of triple cross hybrids as well as new inbreds and F1 hybrids in organic production systems. We will continue to advance material in our breeding programs with testing to produce finished varieties. Impacts What was accomplished under these goals? Impact statement: Most of the corn seed available to organic farmers was not produced organically and the varieties available were not developed to meet the needs of organic corn producers. This project seeks to develop new varieties specifically designed for organic production systems by selection for breeding targets of interest to organic producers and testing in organic production environments. The products of this research will provide organic corn producers with seed options that better meet their needs. We proposed development of a rapid cycle breeding program based on modern maize breeding methods including doubled haploids and genomic selection. In this year, we collected phenotype and genotype data that will be used to train genomic selection models and created a male breeding population. On the female side, we crossed the SHGD trait into a collection of superior inbred lines that will be intermated to create the female population. We proposed to develop triple cross hybrids with superior seed production qualities. In this year, we carried out the first yield trial of a collection of triple cross hybrids. The outcome of this experiment will guide development of improved triple cross varieties.? Publications Type: Journal Articles Status: Published Year Published: 2023 Citation: Trentin, H.U., Yavuz, R., Dermail, A., Frei, U.K., Dutta, S., L&#65533;bberstedt, T. A comparison between inbred and hybrid maize haploid inducers. Plants 12:1095 https://doi.org/10.3390/plants12051095 Type: Journal Articles Status: Published Year Published: 2023 Citation: Aboobucker, S.I., Zhou, L., L&#65533;bberstedt, T. Haploid male fertility is restored by mutations in parallel spindle genes in Arabidopsis thaliana. Nature Plants 9:214-218 10.1038/s41477-022-01332-6 Type: Journal Articles Status: Published Year Published: 2023 Citation: Aboobucker, S.I., L&#65533;bberstedt, T. A genetic mechanism to restore haploid male fertility in Arabidopsis an alternative to chemical methods. Nature Plants 9:205-206 https://doi.org/10.1038/s41477-022-01335-3 Type: Journal Articles Status: Published Year Published: 2023 Citation: Dermail, A., Chankaew, S., Lertrat, K., Suwarno, W.B., L&#65533;bberstedt, T., Suriharn, K. Combining ability of tropical x temperate maize inducers for haploid induction rate, R1-nj seed set, and agronomic traits. Frontiers in Plant Science 14:1154905. doi: 10.3389/fpls.2023.1154905 Type: Journal Articles Status: Published Year Published: 2023 Citation: Dong, D., Nagasubramanian, K., Wang, R., Frei, U.K., Jubery, T.Z., L&#65533;bberstedt, T., Ganapathysubramanian, B. Self-supervised corn kernel classification and segmentation for embryo identification. Frontiers in Plant Science 14:1108355. DOI 10.3389/fpls.2023.1108355 Type: Journal Articles Status: Published Year Published: 2023 Citation: Hintch, T., Lauter, A.M., Kinney, S., L&#65533;bberstedt, T., Frei, U.K., Duangpapeng, P., Edwards, J.W., Scott, M.P. Development of maize inbred lines with elevated grain methionine concentration from a high methionine population. Crop Sci. 63: 2417-2425. https://doi.org/10.1002/csc2.20983 Type: Journal Articles Status: Published Year Published: 2023 Citation: Ledesma, A., Aguilar, F.S., Uberti, A., Hufford, M., Edwards, J., Hearne, S., L&#65533;bberstedt, T. Haplotype sharing and diversity analyses of DH Lines derived from different cycles of the Iowa Stiff Stalk Synthetic Maize Population. Frontiers in Plant Sci. 14:1226072. doi: 10.3389/fpls.2023.1226072 Type: Journal Articles Status: Published Year Published: 2023 Citation: Trentin, H.U., Krause, M., Zunjare, R., Costa Almeida, V., Rotarenco, V., Beavis, W.D., V., Frei, U.K., L&#65533;bberstedt, T. Genetic basis of maize maternal haploid induction beyond MATRILINEAL and ZmDMP. Frontiers in Plant Science 14:1218042. DOI: 10.3389/fpls.2023.1218042 Type: Journal Articles Status: Published Year Published: 2023 Citation: Sanchez, D., Santana, A.S., Morais, P., Peterlini, E., De la Fuente, G., Castellano, M., Blanco, M., L&#65533;bberstedt, T. Genome-wide association analysis of doubled haploid exotic introgression maize (Zea mays L.) lines for agronomic traits under depleted nitrogen conditions. Frontiers Plant Sci. 14:1270166. DOI: 10.3389/fpls.2023.1270166 Type: Journal Articles Status: Published Year Published: 2023 Citation: Fakude M, Frei UK, Foster TL, L&#65533;bberstedt T. Identification of genomic region associated with the causal QTL of SHGD trait in Ames panel by GWAS. The 64th Annual Maize Genetics Meeting. 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Fakude M, Frei UK, Foster TL, L&#65533;bberstedt T. Identification of genomic regions associated with the causal QTL of SHGD trait in Ames panel by GWAS. ASA-CSAA-SSSA. 2023. Type: Journal Articles Status: Published Year Published: 2023 Citation: Bapat, A. R., A. N. Moran Lauter, M. B. Hufford, N. A. Boerman and M. P. Scott, 2023 The Ga1 locus of the genus Zea is associated with novel genome structures derived from multiple, independent non-homologous recombination events. G3 Genes\|Genomes\|Genetics: jkad196. DOI: 10.1093/g3journal/jkad196 Progress 09/01/21 to 08/31/22 Outputs Target Audience: Nothing Reported Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Shelly Kinney is a second year M.S. candidate in the Interdepartmental Genetics Program at Iowa State University. She was trained in breeding for traits that are important for organic producers, such as grain methionine concentration. Mercy Fakude is a second year Ph.D.

student in the Agronomy Plant Breeding and Genetics program at Iowa State University. She was trained in genotyping for genomic prediction. Chris Mujjabi completed is M.S. degree inCrop Science at the University of Illinois. He was trained in doubled haploid technology and genomic predictions. Research technicians Luisa Flores and Leidy Sarmiento managed/lead the Organic Winter Nursery performed from December 2021 to April 2022 and trained six undergraduatestudents from the University if Puerto Rico, Mayaguez (Julio Roman, Pedro Ramos, Arialie Figueroa, Thalia Ramos, Gabriela Martinez, and Ariel Montero) in technical aspects of the field work required for the project. Two UPRM Professor (Angela Linares and Diego Viteri) and three (Julio Roman, Pedro Ramos and Arialie Figueroa) undergraduates students had the opportunity to attend to the Double Haploid Training and the National Plant Breeder Association Meeting held at Iowa State University. Also, Julio Roman, Pedro Ramos (Scott\'s Research Program - USDA) and Arialie Figueroa (Lubberstedt\'s Research program - ISU) spent +8 weeks performing aninternship focused on corn breeding and nursery methods. How have the results been disseminated to communities of interest?Paul Scott presented a seminar in Plant Biology 696, Iowa State University, \"Cross Incompatibility in Corn\". Ames, Iowa, September 29, 2021. Paul Scott was invited to provide information on gametophyte factors to representatives of the popcorn and seed corn industries in two meeting organized by the American Seed Trade Association, December 8, 2021. Thomas Lubbrerstedtpresented a seminar entitled \"Hybrid Horizons\" atthe Texas A&M plant breeingsymposiumam,Febrary 7, 2022. Thomas Lubberstedt presented at the EUCARPIA Maize & Sorghum conferencein Belgrade, Serbia,\"Recent advances in maize doubled haploid technology\", June 2, 2022 When in Puerto Rico to pollinate our winter nursery, Thomas Lubberstedt presenteda seminar on douple haploid technology and the science behind the technology to the staff and students involved in the winter nursery activities What do you plan to do during the next reporting period to accomplish the goals?We will intermate selected inbreds with the SHGD trait to create the male and female popuations required for our rapid cycle breeding program. We will also develop genomic selection models based on our genotype and phenotype data. In addition, we will begin to develop genomic prediction models for triple cross hybrids. We will continue to collect multi-location performance data on lines of interest in order to build more robust genomic prediction models. Next year, we will also initiate our outreach program by holding an organic corn breeding boot camp at our winter nursery site in Lajas, Puerto Rico. Impacts What was accomplished under these goals? The COOP project proposes a two-generation rapid cycling breeding scheme, based on crosses between marker-selected haploid plants in the first generation and haploid induction in the second. Sufficient male and female fertility restoration in haploids with the spontaneous haploid genome doubling (SHGD) trait is a prerequisite. During the summer 2022 season, haploids generated in a background derived from the BS39 population with added SHGD ability were grown in two separate blocks. While one set was strictly self-pollinated, as many as possible cross-pollinations were attempted in the other set, using each haploid only once as a male. Seed set in cross-pollinations was with 65% of the attempted pollinations higher as in strict self-pollinations (54%), as wide anther-silking intervals were not a restricting factor in the crosses. Depending on the number of seed produced per ear, the harvested ears were divided in five groups (1: 1-9 seeds, 2: 10-19 seeds. 3: 20-30 seeds, 4: 30-79 seeds and 5: 80+ seeds). A larger percentage of the ears generated in crosses fell into the groups with less than 20 seed per ear, whereas the self-pollinated ears dominated in the groups with higher seed set, probably due to the fact, that in the crosses any plant showing silk was pollinated, independent if it had restored male fertility or not. It was obvious that plants that had restored male fertility also showed increased female fertility. The scoring for the SHGD trait evaluates the levels of restored male fertility, as this is the major bottleneck in DH production. Female fertility restoration usually is sufficient for self-pollinations and was therefore given less attention. The generated F1 between haploids will be induced during the winter, for another cycle of haploid x haploid crosses in the coming season, and a more thorough evaluation of the female side of the equation. For the marker-based selection aspects of the project, we evaluted genotyping platforms and genotyped 100 of our breeding lines with 8,000 molecular markers. We also obtained test-cross hybrid peroformance data at organic and conventional locations in Iowa and Illinois. These test-cross hybrids included a set of three-way cross hybrids designed for seed production in organic conditions. Publications Type: Journal Articles Status: Published Year Published: 2021 Citation: 1. Boerman N.A., Lauter A.N.M., Edwards J.W., Scott M.P. (2021) Variation in degree of pollen exclusion for ga1-s unilateral cross incompatibility in temperate maize breeding populations, Agrosystems, Geosciences & Environment, John Wiley & Sons, Ltd. pp. e20220. Type: Journal Articles Status: Published Year Published: 2022 Citation: Trampe, B., Batiru, G., Pereira, A.S., G., Frei, U.K., L&#65533;bberstedt, T. (2022) QTL mapping of inducibility using genotype by sequencing in maize. Plants 11: 878 DOI 10.3390/plants11070878 Type: Book Chapters Status: Published Year Published: 2022 Citation: Muhammad-Aboobucker, S., Jubery, Z., Frei, U.K., Foster, T., Chen, Y.-R., Ganapathysubramanian, B., L&#65533;bberstedt, T. (2022) Protocols for in vivo doubled haploid (DH) technology in maize breeding: From haploid inducer to haploid genome doubling. Methods Molecular Biology, Plant Gametogenesis, Methods and Protocols (C. Lambing ed.) 2484: 213-235 https://doi.org/10.1007/978-1-0716-2253-7_16 Type: Journal Articles Status: Published Year Published: 2022 Citation: Trentin, H.U., Batiru, G., Frei, U.K., Dutta, S., L&#65533;bberstedt, T. (2022) Investigating the effect of the interaction of maize inducer and genome backgrounds on haploid induction rates. Plants 11:1527, https://doi.org/10.3390/plants11121527 Type: Journal Articles Status: Published Year Published:

2022 Citation: Santos, I., Verzegnazzi, A.L., Edwards, J., Frei, U.K., De La Fuente, G.N., Zuffo, L., Pires, L.P.M., L&#65533;bberstedt, T. (2022) Usefulness of adapted exotic maize lines developed by Doubled Haploid and Single Seed Descent methods. Theor. Appl. Genet. 135, 1829-1841, https://doi.org/10.1007/s00122-022-04075-2 Type: Journal Articles Status: Published Year Published: 2022 Citation: Sintanaparadee, P., Dermail, A., L&#65533;bberstedt, T., Lertrat, K., Chankaew, S., Suriharn, K. (2022) Seasonal variation of tropical savanna alters agronomic adaptation of Stock 6-derived inducer lines. Plants 11, 2902. https://doi.org/10.3390/plants11212902 Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Fakude, M., Frei, U.K, Ganal, M.W, Bohn, M.O., Scott, M.P and Lubberstedt, T.L., 2022, Incorporating Doubled Haploid technology for more efficient organic corn breeding?, Poster presented at the National Association of Plant Breeders Annual meeting, Ames, Iowa, August 8,2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Bapat, A., Moran Lauter, A.N., Scott, M.P. (2022), Investigations into the genetic structure of Ga1 locus in maize, Poster presented at the National Association of Plant Breeders Annual meeting, Ames, Iowa, August 8,2022. **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience: We primarily reached scientists and students with interest in organic agriculture, plant breeding and genetics with our activities in this reporting period. Benefits of the work extend to farmers who grow organic corn and consumers who consume organic products based on corn such as meat, eggs, milk and corn-based food products. Changes/Problems:Covid-19 presented a serious challenge to the project, limiting our ability to carry out research and present results. By careful prioritization of research activities we were able to keep the research objectives on schedule. Our outreach plan was to host a Corn Breeding Boot Camp at our winter nursery site in Puerto Rico. Becuase of the pandemic, we were forced to cancel the boot camp activities planned for the first two years of the grant. We will hold the remaining Boot Camp activies as planned if it can be done safely according to applicalble guidelines. We will consider requesting a no-cost extension at the end of the grant to hold one of the missed Boot Camps. What opportunities for training and professional development has the project provided?Graduate students Mercy Fakude (ISU), Chris Mujjabi (UIUC), Shelly Kinney (ISU) and Amruta Bapat (ISU) participated in the research project. AB attended the 2021 virtual Maize Genetics Conference and presented a scientific poster to colleagues at the meeting. She attended the Virtual Corn Breeding Research Meeting (February 18-17, 2021) as well. The work performed for the project will be part of the dissertation research required for these student's degree programs. We also trained undergraduate researcher Hannah Clubb in technical aspects of the field work required for the project. Four virtual project meetings were held to ensure project goals are clear to all participants, to develop plans and to present data related to the project. Students received individual training from the PIs and senior project members on their specific research objectives as well. How have the results been disseminated to communities of interest?Graduate student Amruta Bapat attended the 2021 virtual Maize Genetics Conference (March 8-12, 2021) and presented a scientific poster entitled \"Determining functional interactions between pectinmethylesterases encoded by the cross-incompatibility locus, Ga1\" to colleagues at the meeting. Paul Scott and Thomas Lubberstedt virtually attneded the Zemun Polje research confernece (Belgrade, Serbia) and presented talks about gametophyic incompatibility systems and using doubled haploids in maize breeding, respectively. We maintained communication with interested stakeholders through informal interactions by e-mail and phone. What do you plan to do during the next reporting period to accomplish the goals?We will collect genotypic and phenotypic data required for genomic selection as required by the rapid cycle breeding program and make initial models to predict the individuals with the best predictedbreeding values. In addition, we'll advance the male and female breeding cycles using double haploid technology to generate inbred lines for the next cycle of breeding. We'll continue to evalate triple-cross hybrids and high yielding inbred lines for their potential as seed parents in organic seed production systems. **Impacts** What was accomplished under these goals? This year, we selected germplasm and made crosses to initiate the rapid cycling breeding plan described in the proposal. This breeding program utilizes separate breeding populations for male and female parent lines of new hybrids to be tested for performance in organic production systems. The male populaiton is based on BS39cyc-DH lines and already contains the genes for spontaneus haploid genome doubling. The Ga1-S allele that confers exclusion of unwanted pollen was crossed into this population as well. On the female side, we crossed the required genes into genetic backgrounds to be used in the breeding program. We developed a genotyping plan and obtained genotypes of 100 individuals from TraitGenetics to verify that the data is suitable genomic selection as will be reauired in the rapid cycling breeding program. Toward the goal of developing inbreds that are well suited to organic seed production systems, seed for new three way hybrids and high-yielding inbred lines were produced to be evaluated for their utility as seed parents in organic seed production systems. We tested germplasm in Puerto Rico to verify we can make the crosses we need there. Breeding populations were advanced and hybrids were test in joint yield trials carried out in Illinois and Iowa. An unexpected outcome of this work was that the high insect pressure in Puerto Rico allowed selection for insect resistant varieties, including an doubled haploid inducer line that may prove valuable for use in organic enviroments which typically have increased insect pressure. **Publications** - Type: Journal Articles Status: Published Year Published: 2021 Citation: Verzegnazzi, A., Santos, I., Frei, U.K., Krause, M., Campbell, J., Almeida, V., Tonello Zuffo, L., Boerman, N., Lübberstedt, T. (2021) Major locus for spontaneous haploid genome

doubling detected by a case-control GWAS enables efficient doubled haploid line development in exotic maize germplasm. Theor. Appl. Genet. 134: 1423-1434 DOI: 10.1007/s00122-021-03780-8 - Type: Journal Articles Status: Published Year Published: 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 139:1103-1112 DOI: 10.1111/pbr.12857 - 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 - 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 - 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., Verzegnazzi, 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 - 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 - 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 - 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 - 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 - Type: Journal Articles Status: Published Year Published: 2020 Citation: Lu, Y., Moran Lauter, A., Makkena, S., Scott, M.P., Evans, M.M. 2020. Insights into the molecular control of cross-incompatibility in Zea mays. Plant Reproduction. 33: 117-128. ACCESSION NO: 1023509 SUBFILE: CRIS PROJ NO: MIN-02-G07 AGENCY: NIFA MIN PROJ TYPE: OTHER GRANTS PROJ STATUS: NEW CONTRACT/GRANT/AGREEMENT NO: 2020-51300-32177 PROPOSAL NO: 2020-02116 START: 01 SEP 2020 TERM: 31 AUG 2023 GRANT AMT: \$998,650 GRANT YR: 2020 AWARD TOTAL: \$998,650 INITIAL AWARD YEAR: 2020 INVESTIGATOR: Heins, B.; Endres, MA, I. PERFORMING INSTITUTION: UNIV OF MINNESOTA ST PAUL, MINNESOTA 55108 PRE-WEANED CALF REARING OPTIONS FOR ORGANIC DAIRY SYSTEMS NON-TECHNICAL SUMMARY: Our multidisciplinary team conducted advisory interviews and conducted research projects with organic dairy farmers, and we concluded that organic dairy producers are concerned about dairy calf rearing systems and the challenges with calf health in an organic production system to remain viable in the organic dairy industry. The present proposal addresses these challenges through research involving the University of Minnesota\'s West Central Research and Outreach Center\'s certified organic dairy and cooperating organic dairy farms in the region. The overarching goal of our project is to identify organic dairy calf rearing options that promote health and welfare in the organic livestock industry. We will develop methods to investigate the management feasibility of three alternative calf-rearing options: group housing in outdoor super hutches; pair housing of calves; and outdoor housing with the dam on pasture compared to traditional individual housing in outdoor hutches. We will also evaluate markers of calf health, behavior and welfare to ultimately provide recommendations on best calf rearing options for organic producers. Our stakeholder group of organic farmers helped identify and develop the objectives included in this proposal; and they will provide leadership for coordinated on-farm field research and sites for field days. The results of this project will be valuable to organic dairy producers, and will be disseminated to organic producers and industry representatives throughout the United States. Our research results will be shared with our larger stakeholder groups through field days, conferences, publications, and webinars. OBJECTIVES: The long-term goal of this project is to enhance organic dairy production by improving organic dairy calf health and welfare. This overarching goal will be achieved by identifying the best calf housing options that give rise to positive calf welfare by performing a controlled research trial and on-farm studies. Specifically, we will 1)measure and evaluate markers of animal welfare outcomes of health, behavior, and emotional state of calves reared by: 1) individual housing (control); 2) pair housing; 3) group housing; and 4) with dam on pasture, 2)conduct on-farm benchmarking of health measures for each rearing option, and 3)determine the management feasibility through focus groups for each rearing option. The results of this project will be valuable to organic dairy producers, and will be disseminated to organic dairy producers and industry representatives throughout the United States. We willprovide recommendations on best calf rearing options for dairy producers to implement based on welfare outcomes, health benchmarks, and management feasibility. APPROACH: The goal of this project is to identify organic dairy calf rearing options that promote animal welfare. This goal will be achieved by completing project objectives that include: 1) measure and evaluate markers of animal welfare outcomes of health, behavior, and emotional state of calves, 2) conduct on-farm benchmarking of health measures for calf rearing, and 3) to determine the management feasibility through focus groups of calf rearing options. Data collected will be analyzed using models using the SAS Software (2019) for statistical analyses to obtain means

and measurements of error. Models will be adjusted accordingly for each individual research study design. Pen and farm will be the experimental units for the study conducted at the WCROC and for the on-farm study, respectively. For data from calves housed together in pairs, the average of the 2 animals will be calculated, and this will be considered as a single observation. Because the data are means and the variance of a mean of n units is σ2/n, the number of calves per mean will be used as a weighting in the analysis (1 for individually housed calves, 2 for calves housed in pairs, 6 for calves housed in groups and dam-calf pairs). This makes the observations with heavier weight or higher precision more important than others, thus correcting for the imbalance of the design of individual versus group situations (Lensink et al. 2001). A repeated measures analysis will be performed to analyze measures taken more than 3 times on the same experimental unit (i.e. health scores, body weight, etc. for the experiment conducted at the WCROC). However, some measures may be aggregated into 1 measurement to simplify the analyses (i.e. health scores). For some measures (i.e. behavior and cortisol), data will be evaluated using non-parametric methods and logistic regression analysis. Categorical data obtained (i.e. focus groups, surveys, passive immunity success and failure) will be analyzed using a Chi Square test. Treatment means will be separated using multiple comparisons tests (e.g., Tukey or Bonferroni). Data analysis will be planned very carefully to consider all potential interactions and confounding effects. Seasonality and calf birth body weight and physiologic size could be a confounding factor in the analysis. These will all be adjusted for in the statistical analysis. To control for confounding in the analyses, we would either use Stratification and Multivariate methods. Stratification will allow us to fix the levels of confounders and make groups within which the confounder does not vary. Exposure-outcome association within each stratification of the confounder would be created, and therefore, the confounder cannot confound because it does not vary across the exposure-outcome. Stratified analysis works best in the way that there are not a lot of strata and if only 1 or 2 confounders must be controlled. Multivariate methods would be the more accepted form on statistical analysis if there are many potential confounders. Multivariate models can handle large numbers of covariates (and confounders) simultaneously. One method would be to use logistic regression to produce results that can be interpreted as an odds ratio. Logistic regression can control for numerous confounders. Odds ratios can be adjusted other covariates (including confounders). Another statistical analysis to consider is the Analysis of Covariance (ANCOVA) to control for potential confounding variables.For least squares means from ANOVA or ANCOVA, we can adjust the means for the observed marginal distributions of the variable rather than using equal coefficients across classification effects to determine the correct means adjusted for confounding and interaction effects.? Progress 09/01/20 to 08/31/24 Outputs Target Audience:We have reached organic dairy farmers across the United States. Information provide to farmers has been disseminated in print and and audio formats. We have also provided information from the project to veterinarians, organic dairy industry representatives across the United States on the calf housing proejct. We have also trained1 research scientistand 1 graduate student in experimental design and collection of research data. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project has trained organic dairy producers on the housing systems for pre-weaned dairy calves for organic production. Many extension educators and organic industry representatives were informed on housing systems and raising dairy calves at the Minnesota Organic Conference. We have also trained a graduate student in proper experiemental design, data collection, and analysis of data. Graduate stduents from Minnesota presented research on housing systems for organic produciton at the American Dairy Science Association meeting in June 2024 in West Palm Beach Florida. How have the results been disseminated to communities of interest?Over 1000 people have attended presentations related to the objective research in the project. Results were disseminated to academic and audiences through peer-reviewed publications and abstracts presented at conferences. Presentations were also given that included farmers that have used our research results at grazing and organic conferences. We also have small focus group meeting with organic dairy farmers on a monthly basis where we showcased these results from the project. Furthermore, the information was disseminated on The Moos Room podcast. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Calf-rearing practices in pasture-based and organic dairy farms in the Midwest United States.There is an increased societal demand for improved conditions in calfrearing management. Calf-rearing practices in organic and pasture-based dairy farms in the Midwest can be very diverse but are not well documented. This ongoing study aims to describe calf-management practices of organic and pasture-based dairy farms in the Midwest. Pasture-based (at least 120 grazing days per year) dairy farmers in the Midwest received an invitation (emails, social media, farming events, and phone calls) to participate in an in-person survey. Thirteen (certified organic n = 7; certified organic and grass-fed n = 4; transitioning to organic certification n = 1; pasture-based noncertified n = 1) farmers agreed to the in-person interviews, performed with a standard questionnaire with open-ended questions. Due to the diversity of the systems and the low number of farms, only descriptive data analyses are shown. The median herd size was 75.5 cows (34-321 cows). Most farms (67%) separated cows and calves 1 to 48 h after birth. A smaller portion of farms (33%) allowed more than 3 d of full or partial cow-calf contact with the dam or foster cows and reported reduced labor and improved animal health from this practice. Calves separated from cows received 2.4 L to 16 L of milk daily, with 66% of farms feeding 6 L of

milk or less. Milk was offered using one or more of the following methods: buckets with nipples (11%), bottles (33%), buckets without nipples (33%), or mob feeders (66%). Step-down weaning strategies were used on 92% of farms. Calves housed in groups (75%) were the most predominant housing type and were used in combination or as an alternative to individual, cow-calf, or pair housing. Only 36% of organic farmers agreed they could treat diseases in calves using organic-approved options, and 82% reported pneumonia as the most challenging disease to cure. Also, 33% of farms used a vaccination program. This survey demonstrates a high diversity of practices allowing dairy calves to have social contact. Publications Type: Conference Papers and Presentations Status: Accepted Year Published: 2024 Citation: Organic Milk Production in the USA. SUSTAG 8000, November 9, 2023. University of Minnesota, St. Paul Type: Conference Papers and Presentations Status: Accepted Year Published: 2024 Citation: Improving the Health of Organic Dairy Cows & Heifers. Minnesota Organic Conference, January 12, 2024. St. Cloud, Minnesota Type: Conference Papers and Presentations Status: Accepted Year Published: 2024 Citation: Organic Milk Production in the USA. SDSU Dairy Science Class, March 1, 2024. South Dakota State University, Brookings, South Dakota Status: Accepted Year Published: 2024 Citation: Gon&#65533;alves da Costa, B., B. Heins, and M. Endres. 2024. Calf-rearing?practices?in?pasture-based?and?organic?dairy?farms?in?the?Midwest?United?States. . Dairy Sci. Vol. 107, Suppl. 1 (Abstract #2479) p.350 Type: Conference Papers and Presentations Status: Accepted Year Published: 2024 Citation: Pre-Weaned Calf-Rearing Options for Dairy Producer. OREI-PD Meeting, Orlando, FL, April 2024 Type: Conference Papers and Presentations Status: Accepted Year Published: 2024 Citation: Organic Milk Production in the USA. SDSU Dairy Science Class, March 1, 2024. South Dakota State University, Brookings, South Dakota Progress 09/01/22 to 08/31/23 Outputs Target Audience:We have reached organic dairy farmers across the United States, and around the world. Information provide to farmers has been disseminated in many forums.We have also provided information from the project to veterinarians, organic dairy industry representatives across the United States on the calf housing proejct.Afield day was offered for organic dairy producers, extension educators, and organic industry personnel during August 2023. We have also trained 3 undergraduate , 1 research scientist, and 1 graduate student in experimental design and collection of research data. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project has trained organic dairy producers on the housing systems for pre-weaned dairy calves for organic production. Many extension educators and organic industry representatives were informed on housing systems and raising dairy calves on cows at the University of Minnesota organic dairy field day in August 2023. At the field day farmers were interviewed and feedback was provided to researchers about all aspects of the project. A video was produced on farmers providing feedback on the calf housing project and how the project has impacted their operations. The video was shown at an all Extension conference in Minnesota. We have trained 3 undergraduate students on how to conduct research and outreach with housing systems of calves. We have also trained a graduate student in proper experiemental design, data collection, and analysis of data, along with microbiome data anlaysis. Graduate stduents from Minnesota presented research on housing systems for organic produciton at the American Dairy Science Association meeting in June 2023 in Ottawa, Canada. Results from the study were also presented in poster format at the February 2023 MarbleseedOrganic Conference in LaCrosse, WI, and the 2023 Dairy Welfare Council Meeting in May 2023. How have the results been disseminated to communities of interest?We had an in-person organic dairy day at the University of Minnesota West Central Research and Outreach Center in August 2023 to provide farmers and other industry personnel tools that they can take back to their farm when implementing alternative calf housing systems. During the last year, over 150 people have attended the field days at the WCROC. Over 500 people have attended presentations related to the objective research in the project. Results were disseminated to academic and audiences through peer-reviewed publications and abstracts presented at conferences. Presentations were also given that included farmers that have used our research results at grazing and organic conferences. Videos were also produced to elicit feedback from organic dairy farmers on the progress of the project and how the project has impacted their thoughts and dairy operations. What do you plan to do during the next reporting period to accomplish the goals?The investigators on the project continue to review objectives and accomplishments of the project. We continue to collect data for the rearing project, Abstracts and peer-reviewed publications will be drafted. We are collecting data on organic dairy farms to benchmark calf growth. Also, a graduate student will complete her PhD with the project and write 3 peer reviewed publications. Two other peer reviewed publications will be authored by the project investiagators. Impacts What was accomplished under these goals? Growth and health costs of dairy calves raised in individual, pair, or group housing compared to dairy calves raised on cows. The purpose of this study was to investigate growth at weaning and incidence of treatments for scours, respiratory, and other health issues of pre-weaned dairy calves raised in individual (I), pair (P), group (G), or dam- raised (D) housing systems. The study was conducted at the University of Minnesota West Central Research and Outreach Center, Morris, MN. Three-hundred forty-five Holstein and crossbred calves were assigned to housing treatments during 3 fall calving seasons and 2 spring calving seasons from September 2020 to November 2022. The I, P, and G raised calves were enrolled at 3 d and fed 10 L of whole milk per d. Calves raised by their dam were isolated together for 3 d and introduced to a larger cow-calf group where they nursed ad libitum. All calves were weaned at 63 d.

Independent variables were the fixed effects of breed group birthweight, season of calving, and treatment group. Pen within season was a random effect. Hip height for I, P, G, and D calves was not different (P \> 0.05). The D calves had similar heart girth to G calves, but larger (P \< 0.05) heart girth (114.1 cm vs. 111.1 and 110.6, respectively) to I and P calves. The D calves had higher (P \< 0.05) average daily gain (1.15 kg/d vs. 0.98, 0.96, and 0.99 kg/d, respectively), higher (P \< 0.05) weaning weights (112.1 kg vs. 99.7, 99.2, and 102.8 kg, respectively), and higher (P \< 0.05) total gain (74.1 kg vs. 61.9, 60.9, and 64.3 kg/d, respectively) than I, P, and G calves. The D calves had more (P \< 0.05) calves triple their birthweight (52.9%) than I, P, and G calves (12.8, 14.4, and 15.5%, respectively). The G calves had higher (P \< 0.05) health costs (\$5.11/calf) than I, P, and D calves (\$1.23, \$1.16, and \$1.54, respectively). The G calves had a higher (P \< 0.05) incidence for treatment of scours (20.2 vs 7.0 and 9.4%, respectively) than I and D calves. The G calves had a higher (P \< 0.05) incidence for treatment of respiratory problems than I, P, and D calves (15.5 vs 3.5, 1.1, and 3.5%, respectively). Results from this study indicate there may be growth advantages to raising calves with their dams during the pre-weaning period. Seasonality of colostrum BRIX values and total serum protein of newborn dairy female calves in a temperate climate. The aim of this study was to investigate if total serum protein (TSP) of newborn dairy female calves varied between Fall and Spring calving seasons. The experiment was conducted at the University of Minnesota West Central Research Outreach Center (WCROC), Morris, Minnesota. The WCROC has two calving seasons per year: Fall (September to December) and Spring (March toJune). In this study were enrolled 263 female calves from three different breeds Grazecross (n=62), ProCross (n=130) and Holstein (n=71) born during Fall 2020(n=69), Spring 2021 (n=44), Fall 2021 (n=57), Spring 2022 (n=30) and Fall 2022(n=63). Calves were separated from dams during the first day of life and fed 4 liters of colostrum from their dams. Colostrum samples were collected during the first milking after calving and a BRIX value was obtained using a MISCO digital refractometer. Blood samples were collected 24 to 48 hours after birth, centrifuged and (TSP) were obtained using a MISCO digital refractometer. For statistical analysis, the fixed effects included season (Fall or Spring) and BRIX and breed was a random effect for . Year was also included as a fixed effects for BRIX anlaysis. Calves born during Fall (5.8 g/dl± 1.2) had higher (P \<0.01) TSP than calves born during Spring (5.4 g/dl ± 1.0). Breed and BRIX values did not affect TSP. Colostrum brix values did not vary across Fall and Spring seasons (P=0.78). The BRIX value from Fall 2021 was lower than all other seasons (P \<0.05), except for Spring 2021 (P=0.14).The results suggest that seasonality may influence IgG absorption. Milking parlor behavior, body measurements, and body condition scores of first lactation cows raised in individual, pair, or group housing compared to dam-reared housing. The objective of this study was to determine milking parlor behavior, body measurements, and body condition scores of first lactation cows raised in individual (I), pair (P), group (G), or dam- raised (D) housing systems during the pre-weaning period. The study was conducted at the University of Minnesota West Central Research and Outreach Center, Morris, MN. Seventy-nine Holstein and crossbred heifer calves were assigned to housing treatments by birth order and were born from September to December 2020. The I, P, and G raised calves were placed in a housing system at 3 d and were fed 10 L of milk per d. Calves raised by their dam were isolated with the dam for 3 d and introduced to a larger group where they suckled ad libitum. All calves were weaned at 63 d. First lactation cows for the current study calved from September to November 2022. Behavior measurements were from the first 8 milkings after calving. Independent variables were the fixed effects of breed, treatment, milker, and cow and date of measurement were repeated effects. Dam-reared cows had 2.3 ± 0.3 times greater (P \< 0.01) odds of being restless, very restless, or hostile during milking than I, P, and G cows. Furthermore, dam-reared cows had 2.3 ± 0.3 times greater (P \< 0.01) odds of stomping, 4.3 ± 0.4 times greater (P \< 0.01) odds of kicking off the milking unit, and 2.3 ± 0.3 times greater (P \< 0.05) odds of kicking than I, P, and G raised cows. The G cows had larger (P \< 0.05) heart girth than D cows (198.4 cm vs. 189.2 cm), but similar heart girth to I and P cows. The I, P, and G cows had larger (P \< 0.05) rear udder width (5.2 cm, 4.8 cm, and 5.4 cm, respectively) than D cows (4.2 cm). Hip height, body length, pin width, thurl width, rear udder height, body condition score at calving, and body condition score 4 weeks post-calving were not different (P \> 0.05) for I, P, G, and D cows. Results from this study indicate there may be behavioral advantages to raising calves individually, in pairs, or in groups versus raising them with their dam during the pre-weaning period. Social housing: Impacts on health scores and gut microbiome of dairy calves. The aim of this study was to investigate the effects of social housing on the health scores of pre-weaning dairy calves and changes in the gut microbiome during weaning. A total of 343 Holstein (n = 79), ProCross, (n = 169), and GrazeCross (n = 97) calves were evaluated from fall 2020 to fall 2022. At 3 d of age, calves were divided into 4 housing groups: individually housed (n = 87), pair-housed (n = 86), group-housed (6 calves per pen; n = 84), and dam-reared (6 dam-calf pairs per paddock; n = 69) until weaning at 63 d of age. Before weaning there were no differences in microbiome diversity between treatments (P \> 0.05). After weaning, individually housed calves had the tendency to have lower richness (Kruskal-Wallis P = 0.04955; W = 0.08). The microbiome of dam-reared and group-housed calves showed enrichment of gut bacteria such as lactobacilli and bifidobacteria, before and after weaning. Individual housing did not appear to have specific stimulating roles in the calf gut microbiomes. Our results suggest that social housing might affect fecal scores, while simultaneously stimulating the abundance of potentially beneficial bacteria in the gut. Publications Type: Other Status: Accepted Year Published: 2023 Citation: UMN Extension

Moos Room Podcast - June 26, 2023 Episode 176 - Heat stress in dairy calves with Bethany Dado-Senn Type: Other Status: Accepted Year Published: 2023 Citation: UMN Extension Moos Room Podcast -Mar 20, 2023 Episode 162 - UMN WCROC Dairy research update with Dr. Bradley J Heins Type: Other Status: Accepted Year Published: 2022 Citation: UMN Extension\'s The Moos Room - Nov 21, 2022 Episode 145 - How to identify sick calves - Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: Pre-Weaned Calf Rearing Options for Organic Dairy Farms OREI-PD Meeting, Washington DC, April 2023 Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: Putting Organic Dairy Research to Work - Minnesota Organic Conference, January 6, 2023, St. Cloud, MN Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: Pre-Weaned Calf-Rearing Options for Dairy Producers, Minnesota Dairy Inititative Dairy Producer Workshop, Pipestone, MN, December 1, 2022 Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: B. Gon&#65533;alves da Costa, K. Sharpe Moser, M. Endres, and B. Heins.Seasonality of colostrum Brix values and total serum protein of newborn dairy female calves in a temperate climate. J. Dairy Sci. Vol. 106, Suppl. 1 Abstract 2410, p 82. Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: B. Gon&#65533;alves da Costa, A. GOmez, K. Sharpe Moser, M. Endres, and B. Heins.Social housing: Impacts on health scores and gut microbiome of dairy calves. J. Dairy Sci. Vol. 106, Suppl. 1 Abstract 2411, p 82. Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: K. Sharpe and B. Heins. Milking parlor behavior, body measurements, and body condition scores of first-lactation cows raised in individual, pair, or group housing compared to dam-reared housing. J. Dairy Sci. Vol. 106, Suppl. 1 Abstract 2497, p 114. Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: K. Sharpe Moser, B. Gon&#65533;alves da Costa, M. Endres, and B. Heins.Evaluation of growth and health costs of dairy calves raised in individual, pair, or group housing compared to dairy calves raised with dams. J. Dairy Sci. Vol. 106, Suppl. 1 Abstract 2736, p 198. Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: Student Research Presentation: Dairy calves raised individually, in pairs, in groups, or with their dams by Bianca Costa, University of Minnesota. 2023 Dairy Cattle Welfare Symposium, Fort Worth, Texas, May, 2023 **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:We have reached organic dairy farmers across the Midwest and all of the United States. We have also provided information from the project to veterinarians, organic dairy industry representatives across the United States on the disbudding project. A field day was offered for organic dairy producers, extension educators, and organic industry personnel during August 2022. We have also trained 5 undergraduate , 1 research scientist, and 2graduate student in experimental design and collection of research data. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project has trained organic dairy producers on the housing systems for pre-weaned dairy calves for organic production. Many extension educators and organic industry representatives were informed on housing systems and raising dairy calves on cows at the University of Minnesota organic dairy field day in August 2022. We have trained 5 undergraduate students on how to conduct research and outreach with housing systems of calves. We have also trained a graduate student in proper experiemental design, data collection, and analysis of data. Graduate stduents from Minnesota presented research on housing systems for organic produciton at the American Dairy Science Association meeting in June 2022 in Kansas City, Missouri. Results from the study were also presented in poster format at the February 2022 MOSES Organic Conference in LaCrosse, WI. How have the results been disseminated to communities of interest?We had an in-person organic dairy day at the University of Minnesota West Central Research and Outreach Center in August 2022 to provide farmers and other industry personnel tools that they can take back to their farm when implementing alternative calf housing systems. During the last year, over 250 people have attended the field days at the WCROC. Over 500 people have attended presentations related to the objective research in the project. Results were disseminated to academic and audiences through peer-reviewed publications and abstracts presented at conferences. Presentations were also given that included farmers that have used our research results at grazing and organic conferences. What do you plan to do during the next reporting period to accomplish the goals?The investigators on the project continue to review objectives and accomplishments of the project. We continue to collect data for the rearing project, and we begin initial analysis of growth and behavioral data. Abstracts and peer-reviewed publications will be drafted. We will also collect data on organic dairy farms to benchmark calf growth. **Impacts** What was accomplished under these goals? Growth and health costs of dairy calves raised in individual, pair, or group housing compared with dairy calves raised on cows. The objective of this study was to determine growth, health treatment costs, and incidence of treatments for scours, respiratory, and other health issues of dairy calves raised in individual (I), pair (P), group (G), or dam-raised (D) housing systems. The study was conducted at the University of Minnesota West Central Research and Outreach Center, Morris, MN, dairy. Two hundred 39 Holstein and crossbred calves were randomly assigned to housing treatments by birth order during 3 calving seasons from September to December 2020, March to May 2021, and September to November 2021. The I, P, and G calves were introduced to a housing system at 3 d and were fed 10 L of milk per d. Dam-raised calves isolated with the dam for 3 d after birth. After 3 d, the pair was introduced to a larger group where calves suckled ad libitum. All calves were weaned at 63 d. Data were analyzed using PROC MIXED and FREQ of SAS. Independent variables were the fixed effects of

breed, pen, birthweight, season, and treatment, and pen within season was a random effect. Hip height was not different for I, P, G, and D calves. The D calves had higher weaning weight (113.9 kg vs. 99.3, 101.4, and 102.9 kg, respectively), larger heart girth (115.2 cm vs. 111, 111.8, and 112.9 cm, respectively), higher (P < 0.05) average daily gain (1.15 kg/d vs. 0.98, 0.98, and 0.99 kg/d, respectively), and higher total gain (75.5 kg vs. 62.1, 62.0, and 64 kg/d, respectively) than I, P, and G calves. More D calves tripled their birthweight (56.5%) than I, P, and G calves (10.7, 9.3, and 18.3%, respectively). The G calves had higher health costs (\$3.34/calf) than I, P, and D calves (\$1.37, \$0.27, and \$2.20, respectively). Treatments for respiratory and other issues were not different for I, P, G, and D calves. The G calves had greater (P < 0.05) incidence rate for treatment of scours (18.3%) than I, P, and D calves (3.57, 1.85, and 10.14, respectively). The results from this study indicate growth advantages to raising dairy calves with their dams during the preweaning phase. Health assessment of calves raised in alternative rearing systems. The objectives of this study were to investigate the effect of maternal contact on immunoglobulin absorption in the first 24 h of life and the occurrence of diarrhea and respiratory disease in dairy calves raised in alternative systems. Two hundred 41 Holstein (n = 61), ProCross, (n = 118), and GrazeCross (n = 61) calves were evaluated from Fall 2020 to Fall 2021. Analysis of passive transfer of immunoglobulins using total serum protein (TSP) was from a MISCO digital refractometer in 2 groups of calves: 1) separated from the dam (n = 170) and bottle-fed 4 L of colostrum in the first 12 h of life, and 2) dam-reared (n = 69) where calves suckled colostrum naturally. At 3 d of age, calves were divided into 4 housing groups: individually housed (n = 56), pair-housed (n = 54), group-housed (6 calves per pen; n = 60), and dam-reared (6 dam-calf pairs per paddock; n = 69). Dam-reared calves suckled milk naturally, while calves from all other treatments received 10L of milk per day until weaning at 63 d of age. Health scores were collected weekly using the Wisconsin Calf Health Scoring Chart until weaning. Statistical analyses for TSP were performed using PROC MIXED of SAS, and fixed effects were season, breed, and housing group. For health scores, analyses included PROC FREQ and PROC GLIMMIX of SAS with housing type, week, calf, breed, and season as fixed effects. There were no significant breed effects on the treatments. The TSP values were higher in dam-reared calves (TPR: 6.67 ± 0.32) than in separated calves (TPR: 6.16 ± 0.31). In total, respiratory disease was identified in 1.16% of observations, where 0.61% were from dam-reared calves, 0.29% from pair-housed, 0.20% from grouphoused, and 0.06% from individually housed calves. Scours occurred in 4.44% of the observations and was higher in dam-reared calves (6.9 ± 1.01%) than group (4.1 ± 0.75%), pair (1.1 ± 0.35%), and individually (0.5 ± 0.23%) housed calves, but similar in individually and pair-housed calves. The results suggest that dam-reared calves had higher absorption of immunoglobulins and that all rearing systems had a low occurrence of respiratory disease; however, scours were diagnosed more often in dam-reared calves. Lying behavior of dairy calves in alternative rearing systems. The objective of this study was to compare the lying behavior of dairy calves housed in alternative rearing systems before and during weaning. One hundred fifty-nine Holstein, ProCross (Montbéliarde, Viking Red, and Holstein,) and GrazeCross (Normande, Jersey, and Viking Red) calves were evaluated during Fall 2020 and spring 2021. At 3 d of age, calves were fit with IceTag (IceRobotics, Scotland) sensors on the right hind leg and divided into 4 housing groups: individually housed (n = 36), pair housed (n = 34), group-housed (6 calves per pen; n = 40), and dam-reared (6 cow-calf pairs per paddock; n = 49). Lying time and number of lying bouts were recorded daily until 3 d after weaning (d 63). Statistical analysis of lying time and lying bouts were with PROC MIXED of SAS with housing group, breed, and season as fixed effects. Random and repeated effects of calf and date were included in the model. Before weaning and across breeds, dam-reared calves (16.24 ± 0.17 h/d) spent fewer hours lying (P < 0.0001) compared with individually raised (17.91 ± 0.19), pair-housed (17.37 ± 0.19), and group-housed (17.24 ± 0.18) calves. Individually housed calves had more lying hours (P < 0.05) than all other housing systems. Group and pair-housed calves had similar lying times (P = 0.57). During weaning, group-housed (15.11 ± 0.33) had more lying hours per day (P < 0.05) compared with dam-reared calves (13.84 ± 0.28) and individual calves (14.22 ± 0.19). Pair-housed (14.51 ± 0.4) did not differ from any other housing group. There was no difference in the number of lying bouts before weaning; however, after weaning, dam-reared calves (24.17 ± 0.73) had a higher number of lying bouts than group calves (21.6 ± 0.8), but no differences between other housing systems were observed. The results suggest that pre-weaned calves individually housed spent more time resting, while dam-reared calves spent more time performing other activities. During weaning, group-housed calves spent more time resting than dam-reared and individually housed calves. **Publications** - Type: Other Status: Published Year Published: 2022 Citation: Heins, Brad. 2022. Organic Dairy Research News. University of Minnesota. July 2022. 8 pages - Type: Other Status: Published Year Published: 2022 Citation: Nov 29, 2021 Episode 94 - Paired and group housing for dairy calves - UMN Extension\'s The Moos Room - Type: Other Status: Published Year Published: 2022 Citation: Nov 22, 2021. Episode 93 - Brad\'s ADSA Discover Conference report - Calf housing, colostrum, lung ultrasound, and more - UMN Extension\'s The Moos Room - Type: Other Status: Published Year Published: 2022 Citation: Nov 1, 2021 Episode 90 - Feeding dairy calves in the winter - UMN Extension\'s The Moos Room - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Costa, B., K. Sharpe, M. Endres, B. Heins. 2022. Health assessment of calves raised in alternative rearing systems. J. Dairy Sci. Vol. 105, Suppl. 1 Page 15.

Abstr. 1037 - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: K. Sharpe, Costa, B., , M. Endres, B. Heins. 2022.Growth and health costs of dairy calves raised in individual, pair, or group housing compared with dairy calves raised on cows. J. Dairy Sci. Vol. 105, Suppl. 1 Page 23. Abstr. 1061 - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Costa, B., K. Sharpe, M. Endres, B. Heins. 2022. Lying behavior of dairy calves in alternative rearing systems. J. Dairy Sci. Vol. 105, Suppl. 1 Page 47. Abstr. 1192 - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Costa, B., K. Sharpe, M. Endres, B. Heins. 2021. Passive transfer of immunoglobulins and average daily gain of calves in alternative housing systems. 41st ADSA Discover Conference. October 25-28, 2021, Itasca, IL. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: B. Heins and K. Sharpe. 2021. Rearing of Dairy Calves with Cows A Pilot Study 41st ADSA Discover Conference. October 25-28, 2021, Itasca, IL. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Costa, B., K. Sharpe, M. Endres, B. Heins. 2022. Lying time and growth of pre-weaned dairy calves in alternative rearing system. The 14th North American Regional Meeting of ISAE, University of California - Davis, ?April 29 & 30, 2022 - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: B. Heins and K. Sharpe. 2022. Alternative Dairy Management: Nurse Cows, Milk Once a Day, and More. 2022 Grassworks Conference, Wisconsin Dells, WI, Jan 20, 2022 **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience:We have reached organic dairy farmers across Minnesota. We have also provided information from the project to organic dairy industry representatives, and other faculty at universities across the United States on the calf rearing project. A field day was offered for organic dairy producers, extension educators, and organic industry personnel. We have also trained 3 undergraduates and a graduate student in experimental design and collection ofm research data. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project has trained organic dairy producers on the housing systems fororganic dairy calves. Extension educators and organic industry representatives were informed on pre-weaned dairy calf rearing practices at the University of Minnesota organic dairy field day. We have trained 3 undergraduate students on how to conduct research and outreach. We have also trained 1 graduate studentin proper experimental design, data collection, and analysis of data. Faculty from Minnesota presented research on rearing of organic dairy calvesat the 2021 Virtual American Dairy Science Association meeting. How have the results been disseminated to communities of interest?We continue to offer an organic dairy day at the University of Minnesota West Central Research and Outreach Center to provide farmers and other industry personnel tools that they can take back to their farm and make changes. During the last year, over 50 people have attended the field days at the WCROC. Over 100 people have attended presentations related to the objective research in the project. Results were disseminated to academic audiences through peer-reviewed publications and abstracts presented at conferences. What do you plan to do during the next reporting period to accomplish the goals?The investigators on the project continue to review objectives and accomplishments of the project. We continue to collect data for the rearing project, and we begin initial analysis of growth and behavioral data. Abstracts and peer-reviewed publications will be drafted. We will also collectdata on50 organic dairy farms to benchmark calf growth. **Impacts** What was accomplished under these goals? Rearing of Organic Dairy Calves with Cows. The objective of this study was to determine growth and health of organic dairy calves raised on cows compared to calves fed in individual pens or calves raised on an automated calf feeder. The study was conducted at the University of Minnesota West Central Research and Outreach Center, Morris, MN, organic dairy. Forty-five Holstein and crossbred calves were assigned to treatment groups by birth order during one calving season from March to May 2020. Calves raised on cows (n = 14) were housed in a compost bedded pack barn and on pasture, individual calves (n = 16) were housed in single Calf-Tel hutch (Hampel Corp., Germantown, WI), and group calves (n = 15) were housed in an indoor-outdoor barn with a Holm & Laue HL100 Calf Feeder (Holm & Laue GmbH &; Co KG, Westerronfeld, Germany). Calves raised on cows were allowed to bond with the dam for 3 days before being grouped with other calves and cows. Individual and group calves were introduced to hutch and feeder on day 4 and were fed 8 L/d. All calves were weaned at 90 d, and were weighed weekly and scored for health and behavioral measurements. Data were analyzed using PROC MIXED of SAS. Independent variables for analyses were the fixed effects of birthweight as a covariate, treatment group, along with calf within pen as a random effect. At weaning, calves raised on cows had higher (P \< 0.05) weaning weight (137.6 kg vs. 120.0 kg vs. 128.4 kg, respectively) and average daily gain (1.12 kg/d vs. 0.93 kg/d vs. 1.01 kg/d, respectively) compared with individual calves and automated feeder calves. The individual-fed calves and calves from the automated feeder were not different (P \> 0.05) for average daily gain. Average daily gain from birth to120 d of age, was not different (P > 0.05) for all treatment groups. The automated feeder calves had higher (P < 0.05) fecal scores (0.18) compared with calves raised on cows (0.04) and individual calves (0.03). The calves raised on cows had higher (P < 0.05) hygiene scores which indicated calves had dirtier bellies and sides than other treatment groups. The results from this study indicate that there may be advantages to feeding organic dairy calves on cows during the pre-weaning period. In this study, we investigate if dam-calf separation after birth affects the absorption of immunoglobulins in the first 24 hour of life. Additionally, average daily gain (ADG) was evaluated for

calves from alternative preweaning calf-rearing housing during the first 9 wk of life. One-hundred sixty-four Holstein (40.8 kg birth weight), ProCross (Montbéliarde, Viking Red, and Holstein,39 kg birth weight) and GrazeCross(Normande, Jersey, and Viking Red,36.2 kg birth weight) calves were evaluated during Fall 2020 and Spring 2021. At 3 days of age, calves were divided into four housing groups: individually housed (n=36), pair housed (n=34),group-housed (6 calves per pen; n=40), and dam-reared (6 dam-calf pairs per paddock; n=49). Body weights at birth and at 9 wk of age were recorded. Statistical analyses were with PROC MIXED of SAS 9.4, and fixed effects were season, breed, and housing group. Across breeds, dam reared calves (1.21 kg/d ± 0.25) had higher (P < 0.05) ADG compared with individually raised (0.98 kg/d ± 0.13), pair-housed (0.96 kg/d ± 0.14) and group-housed (1.04 kg/d ± 0.17) calves. There was no difference (P > 0.05) in ADG among individual, pair and group-housed calves. Brix (9.45 ± 1.65 for dam-raised calves and 8.76 g/dl± 1.3 for all other calves) and serum total protein (6.2 ± 1.3 for dam-raised calves and 5.6 ± 1.09 for all other calves) was greater for dam-raised calves compared with calves in the other treatment groups. The results suggest that dam-reared calves have higher absorption of immunoglobulins and ADG than calves reared individually, in pairs, or groups. **Publications** - Type: Other Status: Published Year Published: 2021 Citation: Heins, Brad. 2021. Organic Dairy Research News. University of Minnesota. June 2021. 8 pages - Type: Other Status: Published Year Published: 2020 Citation: Heins, Brad. 2020. Rearing of Dairy Calves with Cows. Dairy Star. November 14, 2020 - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Heins, B. J. and K.T Sharpe. 2021. Rearing of organic dairy calves with cows. J. Dairy Sci. Vol. 104, Suppl. 1, p. 177 - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Heins, B. J., M.I. Endres, and K.T. Sharpe. 2021. Preweaned calf rearing options for dairy producers. J. Dairy Sci. Vol. 104, Suppl. 1, p. 351 - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Brad Heins. Rearing of Organic Dairy Calves with Cows. 2021 MOSES Organic Conference Online Seminar. February 26, 2021 - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Pre-weaned calf rearing options for dairy producers. University of Minnesota Extension Winter Dairy Workshop Online. March 26, 2021 - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Pre-weaned calf rearing options for dairy producers. Minnesota DHIA Regional Meeting Online February 24, 2021

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A Multiregional Approach to Balancing Milk and Forage Quality Tradeoffs in Organic Dairies Feeding High-legume Diets

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NON-TECHNICAL SUMMARY

The project long-term goal is to enable farmers to adopt practices that enhance the persistence of legumes in pastures and hayfields and to produce forages with high nutritive value in order to minimize off-farm grain costs, produce milk with enriched fat and protein content, and capitalize on industry premiums. Our research and educational program will synergize the efforts of two premier land-grant organic dairy research farms (University of New Hampshire and University of Minnesota) and the University of Maine to provide farmers with information and actionable strategies for managing mixed grass-legume stands to optimize legume proportion, persistence, and quality. At the same time, we will build a baseline dataset on quality components and phytoestrogen concentrations in forage legumes and milk that will guide future research and extension. Our objectives were developed in consultation with organic dairy stakeholders in our respective regions as part of our recently completed OREI planning grant needs assessment. Team overarching objectives are to (Objective 1) Improve perennial legume abundance and persistence in mixed forage swards utilized for grazing and conserved feed; (Objective 2) Improve forage energy:protein balance, nutritive value, and milk quality components through interseeding practices and selected legume-grass mixtures; (Objective 3) Quantify and mitigate potential impacts of phytoestrogens from legumes on herd reproductive health by evaluating high- vs. low-phytoestrogenic species and how forage conservation methods affect the phytoestrogen contents of hay and silage; and (Objective 4) Develop and deliver educational programing to organic dairy farmers on advanced forage legume management aimed at increasing milk production and quality through webinars, workshops, and on-farm demonstrations. Project impact will be evaluated by The Organic Center and our Research and Extension Advisory Board.

OBJECTIVES

Our research and educational program will synergize the efforts of two premier land-grant organic dairy research farms (University of New Hampshire and University of Minnesota) in collaboration with the University of Maine to provide farmers with information and actionable strategies for managing mixed grass-legume stands to optimize legume proportion, persistence, and quality. At the same time, we will build a baseline dataset on quality components and phytoestrogen concentrations in forage legumes and milk that will guide future research and extension. Our educational program will include the transfer of forage legume information to farmers and other dairy professionals via field days and workshops, a novel international research and education exchange involving our team and colleagues from the Pasture Systems Lab at the University of Western Australia, and

development of a forage quality and phytoestrogen prediction tool to aid dairy farmers in managing the intake of phytoestrogens.Our overarching objectives are to (Objective 1) Improve perennial legume abundance and persistence in mixed forage swards utilized for grazing and conserved feed; (Objective 2) Improve forage energy:protein balance, nutritive value, and milk quality components through interseeding practices and selected legume-grass mixtures; (Objective 3) Quantify and mitigate potential impacts of phytoestrogens from legumes on herd reproductive health by evaluating high- vs. low-phytoestrogenic species and how forage conservation methods affect the phytoestrogen contents of hay and silage; and (Objective 4) Develop and deliver educational programing to organic dairy farmers on advanced forage legume management aimed at increasing milk production and quality through webinars, workshops, and on-farm demonstrations.

APPROACH

Objective 1: Improve perennial legume abundance and persistence in mixed forage swards utilized for grazing and conserved feedA 4-year field experiment will be established at the UNH and UMN-WCROC. The experimental design will be a split-plot with 4 replications. Main-plot treatments will be established in Year 1 (spring) using a grain drill. The main-plot treatment will be sward composition consisting of 6 levels: (T1) alfalfa+grass; (T2) red clover+grass; (T3) white clover+grass; (T4) birdsfoot trefoil+grass; (T5) kura clover+grass, and (T6) grass only. The grass component (orchardgrass, timothy, or meadow fescue) will be held constant across treatments at each site. The split-plot treatment will be 4 combinations of harvest schedule/frequency and defoliation management \residual sward height (RSH) after cutting)\ as follows: defoliation at vegetative stage of maturity at 10-cm RSH (S1) or at 5-cm RSH (S2); and defoliation at mature stage at 10-cm RSH (S3) or at 5-cm RSH (S4). At both sites, defoliation will be performed mechanically using a forage harvester. The split-plot treatments will be applied multiple times each growing season from Years 1-3, depending on treatment. Sward dry matter production and species composition will be assessed over the growing season immediately prior to the clipping associated with the defoliation treatment followed by determination of nutritive value of forage samples.We will also assess the effects of fertility amendment (wood ash or none) and seeding technique (frost seeding vs. spring sowing after close cutting) on the success of interseeding a legume mixture into established pasture/hayfields (measured as % establishment, relative abundance, and persistence) at UNH, UMN-WCROC, and on-farm with 4 farmer collaborators. The legume mixture, which will include kura clover, white clover, and birdsfoot, is intended to pair a common forage legume with moderate phytoestrogenic activity (i.e., white clover) with 2 less-commonly utilized species purported to produce low to no phytoestrogens. Sward dry matter and species composition will be measured.Objective 2: Improve forage E:P balance, nutritive value, and milk quality components through interseeding practices and selected legume-grass mixturesIn Years 2-3, we will conduct grazing studies at UNH and UMN-WCROC. Twenty (UNH) and 40 (UMN-WCROC) mid-lactation dairy cows will be assigned to 1 of 2 treatments in a randomized complete block design: established perennial cool-season pasture or established pasture interseeded with legumes (kura clover, white clover, and birdsfoot trefoil). The experiment will be set up with a 2-week covariate period for baseline data and sample collection followed by a 16-week experimental period over 2 growing seasons. Feed samples will be analyzed for chemical composition including phytoestrogens. Milk samples will be analyzed for fat, protein, milk urea N, fatty acids, and phytoestrogens. Pasture intake and apparent total-tract digestibility of nutrients will be estimated using chromium oxide and in vitro DM digestibility of feeds. Spot urine samples will be analyzed for creatinine, total N, and urea N. Enteric CH4 and CO2 emissions will be measured using voluntary visits to the GreenFeed system throughout the study.In Year 1, established hayfields in NH and MN will be renovated with alfalfa- and red clover-grass mixtures to a targeted legume:grass ratio of 60:40 to be used in winter feeding trials (Year 2). Timothy and meadow fescue will be the candidate grasses. Twenty (UNH) and 28 (UMN-WCROC) mid-lactation dairy cows will be used in a 4 x 4 Latin square design with 21-day periods. Treatments containing the following alfalfa-grass:red clover-grass ratios will be fed (dry matter basis): (1) 100:25, (2) 50:50, (3) 25:75, and (4) 0:100. Diets will be formulated to be isonitrogenous and fed as total mixed rations. Measurements and sampling will be done as reported for the grazing study.In Year 1, hayfields in NH and MN will be renovated or established with kura clover and red clover to a targeted legume:grass ratio of 60:40 to be used in winter feeding trials (Year 3). Twenty (UNH) and 30 (UMN-WCROC) mid-lactation cows will be randomly assigned to 2 treatments in a crossover design with two, 24-day periods. Cows will be fed diets containing 55% red clover-grass baleage or 55% kura clover-grass baleage plus 15% grass hay and 30% concentrate. Measurements and sampling will be done as reported for the grazing study.Data on annual revenues and costs associated with increasing legume proportion will be the basis for a comparative analysis of profitability and risk using stochastic partial budgets. Farm level financial data will be compiled within the experimental treatments and validated using a national database for financial and production farm management data.Objective 3: Quantify and mitigate potential impacts of phytoestrogens from legumes on herd reproductive health by evaluating high- vs. low-phytoestrogenic species and how forage conservation methods affect the phytoestrogen contents of hay and silage.Phytoestrogens have multiple effects on corpus luteum (CL) function. However, the effects of phytoestrogens on the expression of angiogenic proteins have not

been previously investigated. The set of experiments described below will be done with CL and luteal cells obtained from cows fed high (0:100 alfalfa:red clover diet; Year 2) and low (kura clover diet; Year 3) phytoestrogenic rations. For the ex vivo experiments, we will determine the effects of LH on progesterone production. For the in vitro experiments, we will determine the effects of LH, and the phytoestrogens coumestrol, daidzein, genistein, equol and ethyl-phenol, on the expression of progesterone, oxytocin, prostaglandin F2α, basic fibroblast growth factor-2, and vascular endothelial growth factor using mid-cycle luteal cells. A stand of pure red clover will be established at the UMaine Rogers Farm (Orono, ME) on Year 1, divided in 5 plots, and mowed to a cutting height of 5 cm with a disc mower. Each plot (1,000 m2) will be divided into 2 sub-plots, which will be assigned randomly to silage or hay treatments to determine the effects of forage preservation methods on phytoestrogen concentrations.We will utilize an existing national network of organic grass-fed dairies to establish a relationship between bulk tank milk phytoestrogen and pasture phytoestrogen concentrations. At each farm in the Northeast and Midwest (\~20 dairies/year; Years 2-3), bulk tank milk samples will be collected at least once yearly. At the time of sampling, farm-level data will be obtained from DHI or owner records together with legume composition (species) and proportion in either pastures or hayfield. Data generated in Objectives 1 through 3 will be used to develop a simple predictive model that will assist farmers in determining when phytoestrogens may be at problematic levels in their forages.Objective 4: Develop and deliver educational programing to organic dairy farmers on advanced forage legume management aimed at increasing milk production and quality through webinars, workshops, and on-farm demonstrations (All project personnel) The research-based extension programming regarding the role of legumes on milk production and components is a key element of the project. Our outreach effort reflects collaboration among researchers, statewide and county Extension Specialists, NE and MW organic dairy stakeholder organizations, and non-profit advocates. They will work together to evaluate and support the project outreach plan as members of our Research and Extension Advisory Board (see Letters of Support) on an annual basis. We are expecting to engage over 1,500 organic dairy farmers nationwide and an additional 5,000+ agriculture professionals and stakeholders across the Northeast and Midwest through field days, workshops, videos, webinars, factsheets, and peer-reviewed publications. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Project target audience is organic dairy farmers, as well as other relevant organic dairy stakeholders including nutritionists, extension educators, veterinarians, and milk processors across the Northeast, Midwest, and beyond. We are also expecting to engage fellow scientists and undergraduate and graduate students at the national and international level by bringing together the University of New Hampshire, University of Minnesota, University of Maine, and the University of Western Australia. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Project results were disseminated to dairy farmers, dairy nutritionists, extension educators, dairy industry personnel, students, and the scientific community through field days, professional meetings, farmer conferences, webinars, and workshops. Our team capitalized on our previous research focused on legume-grass mixtures and used emerging project data to conduct outreach activities such as workshops, webinars, and field days. Undergraduate and graduate students have been trained on how to conduct experiments, collect samples and analyze data, and advanced lab techniques such as cell cultures and DNA and RNA extractions. In addition, our team has been informing extension educators about the concentration of phytoestrogens in different legume species and the potential negative effect of these plant-derived metabolites on animal reproductive health. How have the results been disseminated to communities of interest?Project results have been disseminated to dairy farmers, dairy nutritionists, extension educators, dairy industry personnel, students, and the scientific community through field days, professional meetings, farmer conferences, webinars, and workshops, and lectures. What do you plan to do during the next reporting period to accomplish the goals?Our team analyze the biomass data in our legume-grass plots and pastures and complete winter and grazing feeding trials. Furthermore, we are planning to continue our work in vitro using cell cultures and in vivo using cows grazing red clover to better understand the role of phytoestrogens on cow reproductive health. We are also planning to continue our outreach activities including delivery of webinars to educated organic dairy farmers and allied industry about the use of legumes in dairy diets and the tradeoffs associated with the concentration of phytoestrogens in legume species such as red clover. Impacts What was accomplished under these goals? Objective 1 University of New Hampshire: Our team continued to quantify total forage biomass at each harvest event in our field experiment at the UNH Kingman Farm. We now have multiple complete years of forage grass and legume biomass data with which to assess harvest treatment effects on forage legume productivity and legume stand persistence and we are currently analyzing the results. University of Minnesota: The objective was to evaluate forage biomass and nutritive value of crops, grasses and legumes grown under organic conditions.Two pasture systems were analyzed across the 2 grazing years (2022 and 2023) at an organic dairy in Morris, MN. Across years, crude protein was highest for monocultures of red clover (22.3%) and alfalfa (22.4%). Pasture biomass was greatest for mixtures of meadow fescue, orchardgrass, and red clover (8,484 kg/ha) followed by meadow fescue, orchardgrass, and alfalfa (7698 kg/ha) and meadow fescue, orchardgrass, and white clover (6103 kg/ha). Orchardgrass (5742 kg/ha) and meadow fescue (4840 kg/ha) had lower biomass in monoculture compared to their inclusion with legumes. White clover (3813 kg/ha) had the lowest biomass in monoculture. Across the grazing season, forage yield was 33%

greater during the spring than fall grazing season, and 45% more than the summer grazing season. Crude protein was greater during the early spring grazing seasons compared to the summer and fall grazing seasons. Objective 2 University of New Hampshire: We aimed to investigate the effect of partially replacing ground corn (GC) with sugarcane liquid molasses (LM) on nutrient digestibility, urinary excretion of nitrogenous metabolits, and the milk concentration of the red clover-derived phytoestrogen equol in dairy cows fed red clover baleage-diets. Twenty organic Jersey cows were used in a randomized complete block design study and fed 60% red clover baleage and 27.7% GC (COR diet) or 22.7% GC and 5% LM (MOL diet). The apparent total-tract digestibility of dry matter and organic matter tended to decrease, and that of crude protein decreased in cows fed MOL vs. COR. In contrast, diets had no effect on fiber digestibility or the urinary excretion of uric acid, allantoin, and total purine derivatives. The urinary excretion of urea N and the proportion of urea N relative to total urinary N and total N intake were all lower with feeding MOL vs. COR. The milk concentration of equol was not affected by diets, indicating that the type of carbohydrate source (starch vs. sugar) likely had no effect on the ruminal microbiota population responsible for converting the phytoestrogens formononetin and daidzein present in red clover into the mammalian phytoestrogen equol. University of Minnesota: Feeding Trial: Organic dairy cows (n =88) were used to evaluate the effect of 2 organic pasture production systems (perennial grass species and perennial grass species with legumes) across the grazing season (May to August 2024) on milk production, milk components, and enteric methane emissions at the UMN organic research dairy in Morris, MN. Preliminary results indicated that cows had similar milk production (17.4 and 17.0 kg/d), fat percentage (3.9% vs. 3.9%), and protein percentage (3.2% vs. 3.2%). Cows in the perennial pasture system had greater methane emissions (365 g/d) compared to cows in the pasture system with improved legumes (290 g/day). Milk fatty acids (FA) study: Montly milk FA data was provided by the Minnesota Dairy Herd Improvement Association from June 2021 to July 2024. Total FA, de novo FA, mixed FA, and preformed FA concentrations (g/100 g milk) and yields (g/d) were analyzed for 250 individual cows. Organic cows grazing improved legume pastures had lower de novo (0.99 g/100g) and higher preformed (1.50 g/100g) and total (3.92 g/100g) FA concentrations than organic cows grazing perennial pastures (1.03, 1.36, and 3.84 g/100g), but produced lower amounts of total FA. Primiparous cows had higher concentrations of total (3.95 g/100g) and preformed (1.50 g/100g) FA than multiparous cows (3.80 and 1.36 g/100g, respectively), but lower amounts of all categories. Further analysis of detailed milk FA profile is needed to better understand individual FA differences across breed groups of FA produced. Objective 3 University of New Hampshire: Co-PD Tsang is currently conducting the second year of a grazing study at the UNH Organic Dairy Research Farm investigating the role of pastures containing red clover on the reproduction function of organic dairy cows. Non-pregnant, non-lactating dairy cows are grazing traditional grass pastures or pastures containing red clover. After completion of the grazing period, corpora lutea will be removed from ovaries and brought to the lab to conduct a series of ex vivo and in vitro experiments. Moisture stress study: Co-PD Smith lab conducted a glasshouse study to investigate how water stress (drought and waterlogging) influences phytoestrogen accumulation in red clover and kura clover. Compared to the red clover control, the 20 d drought resulted in an over 100% increase in the phytoestrogens formononetin and biochanin A, which together accounted for 91−96% of the total phytoestrogens measured. Waterlogging resulted in elevated concentrations of daidzein, genistein, and prunetin. Concentrations of phytoestrogens in kura clover were low or undetectable, regardless of water stress treatment. Leaf water potential was the most explanatory single-predictor of the variation in concentrations of formononetin, biochanin A, and total phytoestrogens in red clover. Climate change study: The accumulation of phytoestrogens in legumes can be influenced by environmental factors. As climate change leads to higher temperatures and CO2 levels, there is growing concern about how this affects phytoestrogen levels in legumes. This study investigates the single and interactive effect of elevated temperatures (eT) and elevated CO2 (eCO2) on phytoestrogen levels in red clover and cowpea. Plants were subjected to eT (35/26°C, day/night) and eCO2(750±50ppm) in the growth chamber for 10 d. Results demonstrate that cowpeas remain non-phytoestrogenic under ambient conditions and single and combined eT and eCO2. In contrast, the phytoestrogen concentration in red clover decreased by 50% under eT and 53% under combined eT and eCO2. Interestingly, eCO2 alone did not influence phytoestrogen the levels in red clover. Overall, increases in temperature associated with climate change may lead to a reduction in phytoestrogen levels in red clover, but not in cowpea. University of New Hampshire and University of Minnesota: Our team collected bulk tank milk samples from several organic grass-fed dairies in the Northeast and Midwest to develop a baseline dataset of the concentration of phytoestrogens in milk, particularly equol has been linked to negatively affect reproductive health of ruminants. Samples are currently being analyzed for phytoestrogens. Objective 4 We established a demonstration plot at the University of New Hampshire Kingman Farm with different legume species and cultivars. Samples collected from the \"legume garden\" showed that the concentration of total phytoestrogens in red clover averaged 4.97 mg/g and was much higher than that found in other legumes such as alfalfa, with clover, birdsfoot trefoil, and kura clover which together averaged 0.084 mg/g. This information has been shared with producers during our outreach events at UNH. Project team members in collaboration with the University of Western Australia visited farms in the region or Perth and presented project results during a legume conference. We e learn from the Australian experience dealing with fertility issues mostly in sheep due to diets

high in subterranean clover. This scientific exchange has been used in project field days and preparation of webinars and written materials. Publications Type: Theses/Dissertations Status: Published Year Published: 2023 Citation: Zamudio A. D. 2023. \"Effects of Wilting Extent on the Phytoestrogen Levels, Nutritional Value, Microbial Populations, and In Vitro Ruminal Methane Emissions of Red Clover Hay and Silage Across Stages. University of Maine, Orono, ME (M.S. thesis; August, 2023). https://digitalcommons.library.umaine.edu/etd/3839 Type: Theses/Dissertations Status: Published Year Published: 2023 Citation: Konopka, A. L. 2023. Replacing Ground Corn With Liquid Molasses In Diets Of Jersey Cows Fed Red Clover Baleage: Effects On Milk Production, Nitrogen Efficiency, Energy Utilization, And Enteric Methane Emissions. University of New Hampshire, Durham, NH (M.S. thesis; September, 2023). https://scholars.unh.edu/thesis/1765 Type: Theses/Dissertations Status: Published Year Published: 2023 Citation: Mumford, M. 2023. An Economic Analysis to Feeding Legume Forages to Organic Dairy Cows. University of Minnesota, Minneapolis, MN (M.S. thesis; November, 2023) https://hdl.handle.net/11299/262857. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Mandal, P., Mortensen, D., Brito, A.F., Lima, M.R.M., Warren, N.D., and Smith, R.G. 2023. Soil Moisture stress influences phytoestrogen concentrations in forage legumes. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America International Annual Meeting, Oct. 29-Nov.01, St. Louis, MO. (Oral presentation) https://scisoc.confex.com/scisoc/2023am/meetingapp.cgi/Paper/152324 Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: J. Garzon, D. Zamudio, M. R. M. Lima, R. A. de Castro, A. P. Jimenez, M. V. Cardoso, C. Knight, and J. J. Romero. 2023. Effects of curing extent on the phytoestrogen levels of red clover hay and silage across storage phases. American Society of Agronomy, Crop Science Society of America and Soil Science Society of America International Annual Meeting,Oct. 29-Nov.01, St. Louis MO (Poster presentation). https://scisoc.confex.com/scisoc/2023am/meetingapp.cgi/Paper/149207 Type: Journal Articles Status: Published Year Published: 2024 Citation: Mandal, P., D. A. Mortensen, A. F. Brito, A. K. Wallingford, M. R. M. Lima, N. D. Warren, and R. G. Smith. 2024. Water stress influences phytoestrogen levels in red clover (Trifolium pratense) but not kura clover (T. ambiguum). J. Agric. Food Chem. 72:1024710256. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Mandal, P., Warren, N.D., Lima, M.R.M., Brito, A.F., and Smith, R.G. 2024. Influence of defoliation frequency and severity on phytoestrogen concentrations in red clover and white clover. Annual Graduate Conference April 15, University of New Hampshire, Durham, USA. (Oral presentation), https://media-gallery.unh.edu/media_submission/1358/?added__year=2024&conference=1&judge_group=8 Type: Journal Articles Status: Published Year Published: 2024 Citation: Lange, M. J., L. H. P. Silva, M. Zambom, K. J. Soder, and A. F. Brito. 2024. Feeding alfalfa-grass or red clover-grass mixture baleage: Feeding alfalfa-grass or red clover-grass mixture baleage: Effect on milk yield and composition, relative abundance of ruminal microbiota taxa, and nitrogen and energy utilization in dairy cows. J. Dairy Sci. 107:20662086. Progress 09/01/22 to 08/31/23 Outputs Target Audience:Project target audience is organic dairy farmers, as well as other relevant organic dairy stakeholders including nutritionists, extension educators, veterinarians, and milk processors across the Northeast, Midwest, and beyond. We are also expecting to engage fellow scientists and undergraduate and graduate students at the national and international level by bringing together the University of New Hampshire, University of Minnesota, University of Maine, and the University of Western Australia. Changes/Problems:A planned grazing study to be conducted at the University of Minnesota did not occur due to logistic issues, which are expected to be resolved and the study resumed in the upcoming year. We are also facing challenges to develop a protocol to analyze phytoestrogens in milk and blood samples. However, co-PD Lima has been working diligently to come up with solutions and she was able to generate encouraging results. What opportunities for training and professional development has the project provided?Project results were disseminated to dairy farmers, dairy nutritionists, extension educators, dairy industry personnel, students, and the scientific community through field days, professional meetings, farmer conferences, webinars, and workshops. Our team capitalized on our previous research focused on legume-grass mixtures and used emerging project data to conduct outreach activities such as workshops, webinars, and field days.Undergraduate and graduate students have been trained on how to conduct experiments, collect samples and analyze data, and advanced lab techniques such as cell cultures and DNA and RNA extractions. How have the results been disseminated to communities of interest?Project results were disseminated to dairy farmers, dairy nutritionists, extension educators, dairy industry personnel, students, and the scientific community through field days, professional meetings, farmer conferences, webinars, and workshops, and lectures. What do you plan to do during the next reporting period to accomplish the goals?Our team will continue to collect biomass data in our legume-grass plots and pastures and conduct additional winter and grazing feeding trials. Furthermore, we are planning to continue our work in vitro using cell cultures and in vivo using cows grazing red clover to better understand the role of phytoestrogens on cow reproductive health. We are also planning to continue our outreach activities do deliver information to organic dairy farmers and allied industry. Impacts What was accomplished under these goals? Objective 1 University of New Hampshire: Our team continued to quantify total forage biomass at each harvest event in our field experiment at the UNH Kingman Farm. We now have multiple complete years of forage grass

and legume biomass data with which to assess harvest treatment effects on forage legume productivity and legume stand persistence. University of Minnesota: The objective was to evaluate forage biomass and nutritive value of crops, grasses and legumes grown under organic conditions. Forages included alfalfa, field peas, meadow fescue, orchard grass, red clover, brown midrib sorghumsudan grass, white clover, and 3 grass and legume mixes with either alfalfa, red clover, or white clover. Forages produced less biomass at Site1 (563.7 kg/ha) and Site2 (446.4 kg/ha) solar sites compared to Site3 (1099.7 kg/ha). The Site2 forages had greater crude protein on a dry matter basis (25.8%) than the Site1 (21.4%) and Site3 (20.9%). The Site2 (57.1%) forages also had greater total tract neutral detergent fiber digestibility than the Site1 (52.5%) and control (51.0%). Additionally, the Site2 forages had greater Ca (1.05%) concentration than Site1 (0.75%) and Site3 (0.84%). Forage biomass and nutritive values varied based on the amount of sun exposure and moisture. Objective 2 University of New Hampshire: Twenty mid-lactation organic certified Jersey cows were assigned to 1 of 2 diets in a crossover design with 2 periods lasting 24 d each. Diets were fed as total mixed ration and contained: (1) 60% second and third cut red clover-grass baleage (30% of each cut) and 40% of concentrate (high red clover-grass mixture diet = HRC), and (2) 30% second and third cut red clover-grass baleage (15% of each cut), 30% second cut alfalfa/white clover-grass baleage, and 40% of concentrate (low red clover-grass mixture diet = LRC). Cows fed HRC had greater digestible energy (DE) intake than those fed LRC due to less fecal energy output. Likewise, intake of metabolizable energy (ME) and net energy of lactation (NEL) increased with feeding HRC vs. LRC. Urinary energy, methane energy, heat production, and milk energy did not differ between diets. Cows fed HRC were more efficient in converting DE into ME and ME into NEL, while cows fed LRC were more efficient in converting ME into milk energy and with less ME lost as heat production. We aimed to investigate the effect of partially replacing ground corn (GC) with sugarcane liquid molasses (LM) on production performance and enteric CH4 emissions in dairy cows fed red clover baleage. Twenty organic Jersey cows were used in a randomized complete block design study and fed 60% red clover baleage and 27.7% GC (COR) or 22.7% GC and 5% LM (MOL). No treatment effect was observed for intake, milk yield, concentration and yield of milk fat, and milk urea N. In contrast, concentration and yield of milk protein, and feed efficiency decreased in MOL vs. COR. Diets did not affect CH4 emissions. We conducted a series of field experiments at the UNH Organic Dairy Research Farm examining the utility of frost seeding red clover into standing pastures to increase the proportion of legumes. In general, frost seeding led to moderate increases in red clover abundance. We also examined the effect of wood ash applications, with the expectation that in plots with wood ash, frost seeded red clover persistence and growth would be enhanced. Our preliminary analysis of these data suggested that wood ash did not influence frost seeding success. University of Minnesota: Co-PD Hadrich developed partial budget models to compare the profitability of incorporating legumes into dairy cow diets. Revenues, operating costs, and ownership costs were collected from for each management plan. The partial budget model results showed that for both scenarios, in the first year of implementation of legumes in the pasture rotation (alternative management plan), profit losses were incurred due to high pasture renovation costs and lower revenue than with a pasture without legumes (current management plan). Both alternative scenarios demonstrated net positive profit and lower incurred costs in the second year, when seed and pasture renovation expenses were not incurred, emphasizing the potential benefits of adopting a legume-pasture feeding method. Objective 3 University of New Hampshire: Non-pregnant, non-lactating dairy cows housed at the UNH Organic Dairy Farm grazed on traditional grass pastures (n=5), or red clover enriched pastures (n=3) for 5 weeks. After the grazing period, corpora lutea (CLs) were removed from ovaries and brought back to the lab to conduct a series of ex vivo and in vitro experiments. Luteal tissue minces from grass fed and red clover fed cows were incubated, ex vivo, at 37C in a shaking water bath, and treated with 10 ng/mL of luteinizing hormone (LH) for 2 h. Progesterone content in the medium was determined by radioimmunoassay. We found that luteal tissue minces from cows that grazed on red clover had lower sensitivity to LH (i.e., made less progesterone) after 2 h of treatment than cows that grazed on traditional grass pastures. In addition, steroidogenic cells were isolated from these CLs, incubated in 6-well plates, and treated with 10 ng/mL LH every 24 h until 168 h, in vitro. For the first 3, 24-h periods, the production of progesterone by luteal cells from cows that consumed red clover, in response to LH, was reduced as compared to cows that grazed on traditional grass pasture. For the 4 remaining 24-h periods, there was no longer a difference in the cellular response to LH between the 2 groups of luteal cells. Together, our data suggests that consumption of phytoestrogen-containing red clover lowered the ability of LH to increase progesterone production, which can compromise ovarian luteal function. Phytoestrogens are known to perform defensive roles and act as electors under various stresses; hence, herbivory can potentially influence the levels of phytoestrogens in legumes. In 2 separate pot greenouse studies, we measured the phytoestrogen concentration in red clover, kura clover, and white clover following herbivory damage by corn earworm. In the first study, 7-d herbivory damage increased 95.5% phytoestrogen levels in red clover but not in kura clover. In the second study, total phytoestrogen levels increased 85% in red clover subjected to herbivory damage for 9 d, and only glycitein concentration increased in red clover after 18 d of damage. Red clover was 86 times more phytoestrogenic than white clover, but there were no differences between red clover cultivars. University of Maine: Our objective was to assess the effects of insufficient (WET) or ample (CUR) curing on the phytoestrogen levels of red clover silage (29.4 and 45.3% DM) and hay (65.1 and

89.1, respectively). Measurements were taken at the start of storage (STRT), after 14 d (MicA), and once storage processes had stabilized for hay and silage (50 and 78 d, respectively; LATE). Samples at each storage stage were analyzed for in vitro gas production (48 h). At STRT, the asymptotic maximal gas production (M) and fermentation rate (k) were not different between CUR and WET hay. However, at MicA, CUR hay had a higher M and k than WET hay. The same was observed at LATE. At STRT, the CUR and WET silage was not different for M and k. A similar trend was observed at MicA and LATE. Objective 4 To better understand the natural variation in phytoestrogen production across legume species and cultivars, we established a \"legume garden\" at the UNH Kingman Research Farm set as demosntration plot. The legume garden includes small plots of over 20 legume species and cultivars, including multiple cultivars of red clover, kura clover, alfalfa, white clover, and many other species. We collected plant material from these plots for phytoestrogen analyses to to educate farmers, students, and industry personal about the concentration of phytoestrogens in different legume species. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Lange, M., L. H. P. Silva, K. J. Soder, M. A. Zambom, and A. F. Brito. 2022. Effect of alfalfa- or red clover-grass mixtures on dietary energy utilization in lactating dairy cows. J. Dairy Sci. (Suppl. 1) 105:122. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Sacramento, J. P., L. H. P. Silva, D. C. Reyes, Y. Geng, and A. F. Brito. 2022. Effect of high versus low red clover-grass mixture on energy utilization in lactating dairy cows. J. Dairy Sci. (Suppl. 1) 105:401. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Ativor, I.N., Warren, N.D., Smith, R.G. 2022. 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Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Hartman, L., Warren, N.D., Smith, R.G., Mortensen, D. (2022) Effects of perennial polyculture management on the weed seedbank community. ASA, CSSA, SSSA International Annual Meeting, Baltimore, MD. Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Mandal, P., A. Wallingford, M. R. M. Lima, A. F. Brito, N. D. Warren, and R. G. Smith. 2023. Do insects increase estrogen-like compounds in animal forages? University of New Hampshire Annual Graduate Research Conference, Durham, NH Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Smith, R.G., Brito, A.F., Warren N.D, Mandal, P., and Ativor, I. 2023. Some Known Unknowns, Unknown Knowns, and Potential Unknown Unknowns Associated with Pasture Legumes for the Dairy Sector: A Northeast US Perspective. Australian Grassland Association Symposium, Perth, Australia. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Zamudio, D., R. A. de Castro, A. P. Jimenez, M. Cardoso, J. Poblete, M. Killerby, and J. J. Romero. 2023. Effect of curing extent on ruminal in vitro gas production kinetics of red clover hay and silage across storage phases. J. Dairy Sci. (Suppl. 1) 106:446. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Konopka, A. L., D. C. Reyes, M. A. Rahman, K. V. Almeida, and A. F. Brito. 2023. Replacing ground corn with liquid molasses in diets containing red clover: Effects on production performance and enteric methane emissions. J. Dairy Sci. (Suppl. 1) 106:443. Type: Journal Articles Status: Published Year Published: 2023 Citation: Warren, N. D., D. A. Cox, and R. G. Smith. 2023. Effects of soil amendments on hairy vetch no-till interseeded into a hayfield. Agronomy J. 115:887-885. Type: Journal Articles Status: Published Year Published: 2023 Citation: Teixeira, C. D., B. T. Castillo, L. Bernhardt, N. D. Warren, C. Petry, J. G. Ernakovich, R. G. Smith, and S. D. Frey. 2023. Frequent defoliation of perennial legume-grass bicultures alters soil carbon dynamics. Plant Soil 490:423434. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Zamudio, D., M. Lima, R. de Castro, A. P. Jimezez, M. Cardoso, C. Knight, and J. J. Romero. 2023. Effects of curing extent on the phytoestrogen levels of red clover hay and silage across storage phases. J. Dairy Sci. (Suppl. 1) 106:193. Progress 09/01/21 to 08/31/22 Outputs Target Audience:Project target audience is organic dairy farmers, as well as other relevant organic dairy stakeholders including nutritionists, extension educators, veterinarians, and milk processors across the Northeast, Midwest, and beyond. We are also expecting to engage fellow scientists and undergraduate and graduate students at the national and international level by bringing together the University of New Hampshire, University of Minnesota, University of Maine, and the University of Western Australia. Changes/Problems:A planned grazing study to be conducted at the University of Minnesota did not happen due to challenges with drought during the summer. We are also facing challenges to develop a protocol to analyze phytoestrogens in milk and blood samples. However, co-PD Lima has been working diligently to come up with solutions. What opportunities for training and professional development has the project

provided?Project results were disseminated to dairy farmers, dairy nutritionists, extension educators, dairy industry personnel, students, and the scientific community through field days, professional meetings, farmer conferences, webinars, and workshops. Our team capitalized on our previous research focused on legume-grass mixtures and used emerging project data to conduct outreach activities such as workshops, webinars, and field days. How have the results been disseminated to communities of interest?Project results were disseminated to dairy farmers, dairy nutritionists, extension educators, dairy industry personnel, students, and the scientific community through field days, professional meetings, farmer conferences, webinars, and workshops, and lectures. What do you plan to do during the next reporting period to accomplish the goals?Our team will continue to collect biomass data in our legume-grass plots and pastures and conduct additional winter and grazing feeding trials. Furthermore, we are planning to continue our with using cell cultures and in vivo using cows grazing red clover. We are also planning to continue our outreach activities do deliver information to organic dairy farmers and allied industry. Impacts What was accomplished under these goals? Objective 1 University of New Hampshire: Our team continued to quantify total forage biomass at each harvest event in our field experiment at the UNH Kingman Research Farm. We now have multiple complete years of forage grass and legume biomass data with which to assess harvest treatment effects on forage legume productivity and legume stand persistence. University of Minnesota: Evaluation of pasture biomass measurements aids producers in knowing the availability of cool season grass in pasture for cattle grazing. Our team continued the study at UMN West Central Research and Outreach Center (Morris, MN) to compare satellite technology with the rising plate meter and forage biomass clippings as a method of pasture monitoring in the Upper Midwest of the USA. The pasture system was composed of cool-season perennials and included mixtures of meadow bromegrass (Bromus riparius Rehmann), meadow fescue (Schedonorus pratensis (Huds.) P. Beauv.), orchardgrass (Dactylis glomerata L.), alfalfa (Medicago sativa L.), red clover (Trifolium pratense L.), and white clover (T. repens L.), and intermediate wheatgrass (Thinopyrum intermedium). Grazing height and forage availability were measured weekly in 9 pastures with a Jenquip pasture plate meter (Jenquip, Feilding, New Zealand). Pastures ranged in size from 2.55 ha to 9.7 ha. Across the summer grazing season, mean forage biomass was 3,267 kg DM/ha (range was 2,864 to 3,622 kg DM/ha) from the plate meter and 2,325 kg DM/ha (range was 985 to 3,321 kg DM/ha) from NDVI satellite images. The correlations for specific pastures of the rising plate meter and the satellite image NDVI ranged from 0.074 to 0.91 and the average correlation was 0.58. Correlations were greater with greater forage availability in the pastures. Alternative methods to calculate the biomass of pastures may provide more advantages for farmers to determine the grazing management of pastures. Objective 2 University of New Hampshire: Twenty mid-lactation organic certified Jersey cows were assigned to 1 of 2 diets in a crossover design with 2 periods. Each experimental period lasted 24 d, with 14 d for diet adaptation and 10 days for sample collection. Diets were fed as total mixed ration and contained (dry matter basis): (1) 60% second and third cut red clover-grass baleage (30% of each cut) and 40% of a ground corn-soybean meal-based mash concentrate (high red clover-grass mixture diet = HRC), and (2) 30% second and third cut red clover-grass baleage (15% of each cut), 30% second cut alfalfa/white clover-grass baleage, and 40% of a ground corn-soybean meal-based mash concentrate (low red clover-grass mixture diet = LRC). Cows fed HRC had greater dry matter intake (21 vs. 20.4 kg/d) than those fed LRC, but no differences were observed for yields of milk and concentrations and yields of milk fat and protein. In contrast, digestibilities of dry matter, organic matter, neutral detergent fiber, and acid detergent increased with feeding HRC than LRC. While cows fed HRC had lower CH4 yield (18.8 vs. 19.6 g/kg of dry matter intake), no differences were observed for CH4 production (mean = 393 g/d) and CH4 intensity (mean = 14.6 g/kg of energy-corrected milk). Cows fed the HRC diet had greater N intake (605 vs. 591 g/d) than cows fed the LRC diet. However, no difference was observed for the concentrations of milk urea N (mean = 12 mg/dL) and plasma urea N (mean = 16.3 mg/dL), and milk N efficiency (mean = 20%). Likewise, the urinary excretion of total N, uric acid, allantoin, and total purine derivatives was not affected by treatments. Objective 3 University of New Hampshire: Studies were conducted at co-PD Tsang\'s lab to determine the effects of daidzein, genistein, and equol on the expression of angiogenic factors, cellular communication network factor 1 (CCN1) and vascular endothelial growth factor (VEGF), in steroidogenic cells obtained from early and midcycle bovine corpora lutea. Specifically, early cycle and midcycle corpora lutea were dissociated with collagenase type I to obtain cells. The cells were seeded into 6-well plates containing serum-free Ham\'s F12 medium supplemented with insulin-transferrin-selenium and allowed to attach overnight. Then, the cells from early cycle corpora lutea were treated with daidzein (0.1, 1 and 10 µm; 3 replicate experiments), equol (0.1, 1 and 10 µM; 2 replicate experiments), or genistein (0.1, 1 and 10 µM; 3 replicate experiments) for 24 h before the conditioned medium was saved for later analysis of progesterone. The cells were immediately extracted for RNA, and reversed transcribed into cDNA to prepare for qPCR for CCN1 expression. The lowest concentration of daidzein (1 µM) seems to be increasing CCN1 expression. Samples were analyzed another angiogenic factor, vascular endothelial growth factor A (VEGFA), and daidzein (1 µM) increased VEGFA expression. Co-PD Tsang is also conducting studies to determine the effects of daidzein and equol on the expression of steroidogenic enzymes (CYP11A1, 3βHSD) in steroidogenic cells obtained from early and midcycle bovine corpora lutea. Following the same protocol described above, preliminary results revealed that daidzein (10 µM) appeared to increase the expression of CYP11A1 in

cells obtained from the early cycle and midcycle bovine corpora lutea. However, no clear trend was evident regarding the effect of daidzein on the expression of 3βHSD. University of Maine: Our objective was to assess the effects of insufficient (WET) or ample (CUR) curing on the phytoestrogen levels of red clover silage (29.4 and 45.3% DM) and hay (65.1 and 89.1, respectively). Measurements were taken at the start of storage (STRT), after 14 d (MicA), and once storage processes had stabilized for hay and silage (50 and 78 d, respectively; LATE). Data were analyzed as a randomized complete block design (5 blocks) with a 2 (curing extents) x 2 (storage methods) x 3 (storage phases) factorial. The concentration of formononetin was higher in silage vs. hay at STRT (4,624 vs. 2,893 ± 175 mg/kg of DM, respectively), MicA (5,383 vs. 2,110), and LATE (5,666 vs. 2,569). Also, more formononetin was found in WET vs. CUR silage (5,841 vs. 4,608.1 ± 154 mg/kg of DM, respectively). However, no differences were observed between WET vs. CUR hay. At STRT, biochanin A was higher in silage vs. hay (3,105 vs. 2,012 ± 139 mg/kg of DM, respectively). A similar trend was observed at MicA (3,233 vs. 1,057), and LATE (3,295 vs. 1,228). In addition, more biochanin A was observed in WET vs. CUR silage (3,793 vs. 2,628.9 ± 127 mg/kg of DM, respectively). The opposite was observed in WET vs. CUR hay (1,219.5 vs. 1,644.9). The genistein concentration was higher in silage vs. hay at STRT (149 vs. 120 ± 8.36 mg/kg of DM, respectively), MicA (246 vs. 62.6), and LATE (264 vs. 72.9). Also, the concentration of genistein was higher in WET vs. CUR silage (236 vs. 202.3 ± 7.21 mg/kg of DM, respectively) but the opposite was observed in WET vs. CUR hay (72.8 vs. 97.3). In the case of daidzein, hay had a higher concentration of this phytoestrogen than silage (12.8 vs. 6.67 ± 0.43 mg/kg of DM, respectively). Objective 4 An in-person organic dairy day was conducted at the University of Minnesota West Central Research and Outreach Center to provide farmers tools that they can take back to their farm when implementing forages for pastures. During the last year, over 250 people have attended the field days at the WCROC. Over 500 people have attended presentations related to the objective research in the project. Similar outreach activities were conducted at UNH Organic Dairy Research Farm and UNH Kingman Farm hiligh Publications Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Sacramento, J. P., L. H. P. Silva, D. C. Reyes, Y. Geng, and A. F. Brito. 2021. Feeding legume-based forages: Effects on N utilization in dairy cows. J. Dairy Sci. (Suppl. 1) 104:306307. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Hutchings DW, Elder D, Tsang PCW. 2022. Does the Phytoestrogen Daidzein Stimulate Angiogenic Factors in Bovine Steroidogenic Luteal Cells? 56th Annual Meeting of the Society for the Study of Reproduction, Spokane, Washington, July, 2022. Type: Other Status: Other Year Published: 2022 Citation: Donnelly Hutchings. Phytoestrogens and Ovarian Function: The Good and the Bad. Graduate Seminar, University of New Hampshire, Department of Molecular, Cellular and Biomedical Sciences, April 19, 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Clemente L. D. and B. J. Heins. 2022. Evaluation of pasture biomass from cool-season and Kernza pastures with satellite imagery compared to an electronic plate meter. J. Dairy Sci. Vol. 105 (Suppl. 1):245. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: D. Zamudio-Ayala, R. A. De Castro, M. Killerby, G. Oppong, C. Knight, K. Dean, and J.J. Romero. 2022. Effects of curing extent on red clover hay and silage nutritional value and microbial population across storage phases. J. Dairy Sci. Vol. 105 (Suppl. 1). Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Sacramento, J. P., L. H. P. Silva, D. C. Reyes, Y. Geng, and A. F. Brito. 2021. Feeding legume-based forages: Effects on milk yield, nutrient digestibility, and methane emissions in dairy cows. J. Dairy Sci. (Suppl. 1) 104:307. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: D. Zamudio-Ayala, R. A. De Castro, M. Killerby, G. Oppong, C. Knight, K. Dean, and J.J. Romero. 2022. Effects of curing extent and storage time on dry matter loss, nutritional value, microbial counts, and heating of aerobically exposed red clover silage. J. Dairy Sci. Vol. 105 (Suppl. 1). Type: Journal Articles Status: Published Year Published: 2022 Citation: Payette, M., M. R. M. Lima, W. M Coleman, and M. Ashraf-Khorassani. 2022. Separation optimization and quantitative analysis of phytoestrogens employing reverse-phase high-performance liquid chromatography with UV-VIS detection. Journal of Liquid Chromatography & Related Technologies. 44:888-896 Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Clemente L. D. and B. J. Heins. 2022. Evaluation of pasture biomass with satellite imagery and an electronic plate meter and comparison of cool-season pastures with Kernza pastures. 2022 MOSES Organic Farming Conference, LaCrosse, WI. February 24-26, 2022 Progress 09/01/20 to 08/31/21 Outputs Target Audience:Project target audience is organic dairy farmers, as well as other relevant organic dairy stakeholders including nutritionists, extension educators, veterinarians, and milk processors across the Northeast, Midwest, and beyond. We are also expecting to engage fellow scientists and undergraduate and graduate students at the national and international level by bringing together the University of New Hampshire, University of Minnesota, University of Maine, and the University of Western Australia. Changes/Problems:Some project activities were delayed due to the COVID-19 pandemic and persistent supply issues. What opportunities for training and professional development has the project provided?Project results were disseminated to dairy farmers, dairy nutritionists, extension educators, dairy industry personnel, students, and the scientific community through field days, professional meetings, farmer conferences, webinars, and workshops. Our team capitalized on our previous research focused on legume-grass mixtures and used emerging project data to conduct outreach

activities such as workshops, webinars, and field days. We also hired graduate students who are currently being trained to perform cell culture, extract RNA, generate complementary deoxyribose nucleic acid (cDNA), perform primer verification using polymerase chain reaction (PCR) and agarose gel electrophoresis, and conduct real time PCR. In addition, students were trained to conduct feeding trails, agronomic and agroecology research, and economic analyses. How have the results been disseminated to communities of interest?Project results were disseminated to dairy farmers, dairy nutritionists, extension educators, dairy industry personnel, students, and the scientific community through field days, professional meetings, farmer conferences, webinars, and workshops. What do you plan to do during the next reporting period to accomplish the goals?Our team will continue to collect biomass data in our legume-grass plots and pastures and conduct additional winter and grazing feeding trials. We are also planning to continue our outreach activities do deliver information to organic dairy farmers and allied industry. Impacts What was accomplished under these goals? Objective 1 University of New Hampshire (UNH): A four-year field experiment was established at the UNH Kingman Research Farm to examine the effects of harvest frequency (3 versus 5 cuts per season) and cutting height (5 cm versus 10 cm residual forage height) on perennial forage legume productivity and persistence. Forage legumes included alfalfa, red clover, white clover, and birdsfoot trefoil, each grown in biculture with orchardgrass. All treatment combinations are replicated 5 times. In year 1 we quantified total forage biomass at each harvest event by sampling from two 0.25 m2 quadrats randomly placed within each replicate just prior to harvest. Biomass was sorted to species, dried to constant weight, and weighed. University of Minnesota: Evaluation of pasture biomass measurements aids producers in knowing the availability of cool season grass in pasture for cattle grazing. The objective of this study was to compare satellite technology with the rising plate meter and forage biomass clippings as a method of pasture monitoring in the Upper Midwest of the USA. The study was conducted at the University of Minnesota West Central Research and Outreach Center, Morris, MN grazing dairy from May 2021 to October 2021. The pasture system was composed of cool-season perennials and included mixtures of meadow bromegrass (Bromus riparius Rehmann), meadow fescue (Schedonorus pratensis (Huds.) P. Beauv.), orchardgrass (Dactylis glomerata L.), alfalfa (Medicago sativa L.), red clover (Trifolium pratense L.), and white clover (T. repens L.), and intermediate wheatgrass (Thinopyrum intermedium). Grazing height and forage availability were measured weekly in 9 pastures with a Jenquip pasture plate meter (Jenquip, Feilding, New Zealand). Pastures ranged in size from 2.55 ha to 9.7 ha. Satellite images were obtained from Planet Labs PBC (San Francisco, CA) and average normalized difference vegetation index (NDVI) values were calculated weekly for the area inside each pasture. Pearson correlations were done using the PROC CORR of SAS 9.4 and determined associations of forage biomass from the plate meter and satellite imagery. Data are currently being analyzed. Objective 2 University of New Hampshire: Data from a feeding trial conducted at the UNH Organic Dairy Research Farm was used to evaluate the effect of diets with different legume-grass mixtures on diversity and relative abundance of the ruminal microbiota. Specifically, 20 Jersey cows (18 multiparous and 2 primiparous) averaging 148 days in milk and 483 kg of body weight in the beginning of the study were used in a randomized complete block design with repeated measures over time. Cows were fed diets containing (dry matter basis) 35% of a concentrate mash and the following forage sources: (1) 65% second- and third-cut (32.5% each) alfalfa-grass mixture baleages (ALF) or (2) 65% second- and third-cut (32.5% each) red clover-grass mixture baleages (RC). The Shannon and Faith α diversity indices were both lower in cows fed RC than ALF, thus indicating less richness or evenness of the ruminal fluid prokaryotic community in the RC diet. In agreement, the β diversity was greater with feeding RC than ALF in week 4 of the study, but no difference was detected in week 7. There was no treatment effect on the relative abundance of the archaeal community in ruminal fluid. A diet by week interaction was found for the relative abundance of the rumen bacterial phylum Verrucomicrobiota. Cows fed RC had greater relative abundance of Verrucomicrobiota than those fed ALF in week 4, but no difference between diets was found during week 7. A diet by week interaction was also observed for the bacterial genus WCHB1-4, which is an uncultured genus member of the Verrucomicrobiota phylum that has been identified as part of the core microbiome of dairy cows. Further, we saw a diet by week interaction for the bacterial phylum Fibrobacterota showing that cows fed RC had greater relative abundance of Fibrobacterota in week 4 than those fed ALF, with treatments being similar during week 7. An interaction effect was also detected for the relative abundance of ruminal Fibrobacter, which increased in RC versus ALF in week 4 but did not change in week 7. Compared with cows fed ALF, RC cows had lower relative abundance of p-251-o5, which is an unclassified ruminal genus of the order Bacteroidales commonly reported in ruminants. Objective 3 University of New Hampshire: Studies were conducted at co-PD Tsang\'s lab to confirm the presence or absence of the nuclear and membrane estrogen receptors in steroidogenic cells obtained from early and midcycle bovine corpora lutea. The classical estrogen receptors belong to the super family of nuclear receptors, designated as estrogen receptor alpha (ERα) and estrogen receptor beta (ERβ). Both forms of the nuclear estrogen receptor are present in bovine corpora lutea obtained from slaughterhouse ovaries. More recently, a non-genomic membrane receptor, GPR30, has been found, but to our knowledge, it is not known if GPR30 is expressed by the bovine corpus luteum. Polymerase chain reaction (PCR) primers for all three estrogen receptors were designed and validated using extracts of steroidogenic cells from early cycle and midcycle bovine corpora lutea. Using these primers, the resulting PCR products were

separated on agarose gels. Single bands were detected, confirming the presence of both forms of nuclear receptors and the membrane receptor. We also decided to determine if daidzen and equol might regulate the expression of ERα and ERβ in steroidogenic cells from the early cycle corpus luteum. These experiments are in progress, and so far, the results are mixed, making conclusions difficult. University of Maine: Co-PD Romero planted 0.5 h of the red clover variety Freedom to establish the forage crop for producing silage and hay using mini-silo and mini-hay techniques. Objective 4 Our team delivered field days, pasture walls, webinars, and workshops. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Almeida, K. V., L. H. P. Silva, J. P. Sacramento, D. C. Reyes, R. G. Smith, N. Warren, and A. F. Brito. 2021. Effects of seeding intensity and cutting on the nutritional quality of grass-legume mixtures. J. Dairy Sci. (Suppl. 1) 104:249. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Lange, M. J., L. H. P. Silva, M. Ghelichkhan, M. A. Zambom, and A. F. Brito. 2021. Feeding alfalfa- or red clover-grass mixtures: Effects on methane emissions and plasma amino acids in dairy cows. J. Dairy Sci. (Suppl. 1) 104:101. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Hutchings, D., and P. Tsang. 2021. Do the Phytoestrogens Daidzein and Equol Impact the Expression of Cellular Communication Network Factor 1 (CCN1) and Vascular Endothelial Growth Factor a (VEGFA) in the Young Bovine Corpus Luteum (CL)? (Award of Excellence, poster, University of New Hampshire, College of Life Sciences and Agriculture, Undergraduate Research Conference). Type: Theses/Dissertations Status: Published Year Published: 2021 Citation: Sacramento, J. P. 2021. Energy nutritional requirements and dietary strategies for lactating dairy cows under different production and climatic conditions. Federal University of S&#65533;o Jo&#65533;o del-Rei, S&#65533;o Jo&#65533;o del-Rei, Minas Gerais, Brazil (Ph.D. Dissertation). Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Lange, M. J., L. H. P. Silva, M. Ghelichkhan1, M. A. Zambom, and A. F. Brito. 2021. Feeding alfalfa- or red clover-grass mixtures: Effects on production and milk fatty acids in dairy cows. J. Dairy Sci. (Suppl. 1) 104:101.

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Taking Tillage Out of Organic Grain Crop Production with Ecology, Tools and Technology

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NON-TECHNICAL SUMMARY

Organic field crop and dairy farmers in the Northeast and Upper Midwest are facing extraordinary challenges related to an increased frequency of extreme weather events that restrict crop production. Additionally, there is increased market competition from both imported organic grain and industrial farms that have transitioned to organic production. Transformative changes are needed to address these challenges and meet the goals of the OREI program. Building on decades of combined experience using rolled-crimped cover crops and cultural weed management practices to replace tillage in organic field crop production, we will help organic farmers increase profitability and resilience to extreme weather by 1) redesigning crop rotations to enable extended sequences of no-till production, 2) integrating cultural, mechanical, and electric weed control practices for reducing weed populations and weed-crop competition, and 3) developing adaptive management decision support tools to optimize cropping system performance. Central to our transdisciplinary project is a farmer-focused co-learning approach to research and extension where organic farmers work together with researchers on experiments and are involved in direct farmer-to-farmer learning. New curriculum will be developed for an undergraduate course on organic agriculture at Cornell University and modules will be shared with professors at other universities. Project activities will culminate in an international summit on organic no-till crop production held at the University of Wisconsin-Madison campus. There, farmers, researchers, extension educators, and other agricultural service providers will work together to catalyze adoption of organic no-till cropping systems, while undergraduate and graduate students connect their curriculum to real-world applications.

OBJECTIVES

Project Goal and Objectives. Our long-term goal is to develop robust management strategies for reducing tillage in organic grain and forage based cropping systems and facilitate the transformation to a more sustainable agriculture that better balances tradeoffs between productivity, environmental impact, and farmer quality of life. We will achieve our long-term goal through the following five objectives:1. Test adaptive management strategies and new weed management tools for optimizing organic no-till soybean production.2. Develop an organic reduced-tillage cropping system for grain and forage production that decreases soil disturbance across an extended sequence of crops in a rotation.3. Conduct a series of on-farm research and demonstration trials to develop a real-time decision support tools for management of cereal rye in an organic no-till soybean phase.4. Develop extension tools and activities to facilitate farmer-to-farmer learning, create on-line videos and a

production guide and host an international summit on organic no-till production.5. Train the next generation of farmers, agricultural service providers, and educators by developing course modules and experiential learning activities focused on organic no-till.

APPROACH

Activity 1a. The Self-Seeding in Organic Soybean Experiment will be initiated in September 2020 on certified organic land at Cornell and UW Agricultural Research Stations. The field experiment will be repeated each year in a different field at both sites for a total of 6 site-years. The experiment design will be a split-split-split randomized complete block with two levels of four different factors. We will measure soil temperature (Watchdog data loggers) and soil moisture (neutron probe) continuously in rolled cover crop and tillage-based plots to better understand weed suppression and competition. Ground cover of cereal rye will be measured using Canopeo. Protocols and sampling methods will be similar to those used in previous research.Activity 1b. The Supplemental Weed Management in Organic No-till Soybean Experiment will be initiated in September 2020 by seeding cereal rye in certified organic land at Cornell and UW Agricultural Research Stations. The field experiment will be repeated each year in a different field at both sites for a total of 6 site-years. The experiment will be designed as a split-plot randomized complete block with four treatments: 1) Standard management (rolled-crimped cereal rye alone); 2) High-residue cultivation, 3) Inter-row mowing, and 4) Electric weed zapper (Fig. 7). Each main plot (40 × 120 ft) will be split to evaluate weed management efficacy under ambient weed populations and supplemented weed seed bank conditions. Cover crop and soybean planting will occur in a single pass operation at cereal rye anthesis as described above. Activity 2a. The Reduced-tillage Rotation Experiment will be initiated in September 2020 on certified organic land at Cornell and UW agricultural Research Stations. This experiment will strive towards a viable, continuous organic no-till crop rotation by building upon existing organic no-till management research of summer annuals, grains, and winter annual cereals. This continuous organic no-till crop rotation will consist of linking together established rolled-crimped system crop couplets of a) cereal rye-soybean, b) buckwheat-winter wheat and c) hairy vetch-corn by employing cultural weed management tactics, utilizing no-till seeding equipment, reducing weed seed rain via strategic mowing & forage harvests, exploiting cover crop competition and biology, and implementing innovative weed management tools. Activity 2b.We will compare production across several winter and summer cash crops that are no-till planted into rolled-crimped cover crops. This experiment will be conducted at the Cornell and UW Agricultural Research Stations. Using a gradient of crop species representing different plant families that have beneficial traits with respect to management and market options, we will examine biotic (pests, cover crop growth, etc.) and abiotic (soil moisture, soil nutrient, temperature, etc.) factors that affect cash crop establishment, growth, productivity, and profitability. Expenses and labor will be tracked in each treatment and assessed along with crop yields to calculate profitability. Prior to grain harvest, we will evaluate the density and biomass of each weed species within a 0.5 m2 quadrat in each experimental unit. Weed community structure will be assessed through multivariate analysis (e.g., nonmetric multidimensional scaling, PERMANOVA, indicator species analysis). Structural Equation Models (SEM) will be used to evaluate the relative contributions of nutrient availability, allelopathy, and phylogenetic relatedness. Activity 2c. We will test the effect of rolled cover crops on white mold in several of the main crops (soybean, sunflower and dry bean) within Activity 2c at the Research North facility of Cornell AgriTech at the NY State Agricultural Experiment Station, Geneva, NY. This field is transitioning to certified organic production and has been uniformly inoculated with S. sclerotiorum for six consecutive years. The experiment will be repeated twice in different positions of the field over the course of this project. Activity 3. Using a co-learning approach, we will conduct a series of research and demonstration trials at collaborating organic farms in the Upper Midwest and Northeast to evaluate adaptive management strategies, develop decision support tools, and refine management practices and strategies tested in Objectives 1 and 2. On-farm research will focus on timing of no-till planting soybean and other cultural weed management practices in addition to testing new weed management tools, including inter-row mowing and electric weed zapping. Activity 4a. A core group of six organic grain and dairy farmers have agreed to actively assist with our research program and serve as regional representatives. These farmers will then become peer leaders sharing expertise, experiences, and perspectives at workshops and on-farm field days. On-farm field days, using the \"seeing-is-believing\" strategy, are an important part of our effort to promote strategies for reducing soil tillage across organic grain rotations. In each year, at least one cooperating farmer will host an on-farm field day, organized by the farmer, a co-PD, and local Extension staff. Field days will highlight project results and innovative farm practices. Activity 4b. We will prepare research reports for organic farmers in each year of the project and distribute them to farmers at outreach events and via websites. We will create and distribute a quarterly newsletter via email to project stakeholders, collaborators, and interested farmers. The newsletter will take a broader and more informal approach than the annual research reports. It will feature introductions to the team, project profiles, photos from the experiments, tool updates, and applicable stories about organic no-till production from other researchers outside the project. In addition to email, the quarterly newsletters will be available online through the existing university websites. In year 4, we will also

publish an extensive Organic No-till Crop Production Guide based on our research data, other relevant research, and producer experience.Activity 4c. We will organize the International Organic No-Till Summit and bring together people who are interested in organic no-till from around the world. The summit will be held in January 2024 in partnership with the OGRAIN Winter Conference in Madison, WI, thus allowing for efficiencies in facilities costs and speaker travel, as well as ensuring strong farmer participation to complement the research presentations.Activity 5. We will engage students with experiential learning activities that increase their understanding of organic no-till crop production, weed ecology, soil science, systems research, and agroecological theory. Students will learn about using cover crops to reduce tillage in organic crop production by visiting field research sites. Student learning objectives include: 1) introduction to the role of no-till agriculture as a way to adapt to changing weather patterns from climate change, 2) understanding adaptive management through using our decision support tool on theoretical scenarios, 3) developing capacity to formulate solutions to weed management challenges in organic production, and 4) fostering an appreciation of co-learning with farmers during field trips to the farms of our participating advisory board. *No reports since 2022 as of June 2025* **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:Target audiences reached during this reporting period were organic farmers in the Upper Midwest and the Northeast regions who grow grain crops (soybean, dry bean, small grains) as well as forages, and who have struggled with decreased profitability over the past several years due to challenges from extreme weather, pest outbreaks, or weaker markets. Our farmers benefitted by receiving education on no-till systems from field days, virtual workshops, farmer meetings, research presentations, and online videos. Farmers were able to view novel weed management tools like the Weed Zapper and Inter-row Mower. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? The project has offered five undergraduate student researchers an opportunity to learn about agriculture research within no-till organic systems. Two Masters students and one PhD student managed field experiments related to this project, gaining experience in study design, developing and refining protocols, and interfacing with stakeholders through demonstrations and field days. Research technicians have gained experience in refining sampling protocols and methods, weed identification, and organic no-till management techniques. How have the results been disseminated to communities of interest? Results have been distributed through field days, farmer-advisory board meetings, scientific and farmer conferences, virtual conferences, and a no-till organic soybean growers guide. What do you plan to do during the next reporting period to accomplish the goals? The experiments New Crops for Organic No-till, Soybean Integrated Weed Management, and Starter Fertilizer will be written up and submitted to academic journals. Economic and labor analyses will be conducted and shared with farmers. We will hold a farmer-advisory board meeting in February 2023. Undergraduate student feedback from learning modules will be incorporated to further refine content. A farmer-hosted field day is being planned for 2023. **Impacts** What was accomplished under these goals? Objective 1 relates to optimizing new weed management tools for organic no-till soybean production. 1) Major activities completed: During this reporting period, we conducted the second year of the supplemental weed management study. Nine treatments featured high soybean seeding rates, inter-row mowing, weed zapping, and combinations of these treatments compared to a no-management control. All data are now collected and analyzed, and a journal article is in progress. 2) Data Collected: Cereal rye and weed species biomass, soybean biomass, and soybean yield and density. In 2022, visual estimates of weed cover and weed seed production and maximum seed production in control plots were also collected. 3) Results: the interrow mower suppressed weed biomass in all treatments compared to the control. The combination of the high seeding rate and interrow mower increased soybean yields compared to the control. 4) Key outcomes: Concerns about sole reliance on cover crop mulch for weed suppression and the inability to manage weeds has been cited by farmers as a limitation preventing greater adoption of organic no-till soybean. This research provides insight into the role of specialized weed-management equipment for this system. Objective 2 relates to developing an organic reduced-tillage cropping system that decreases soil disturbance, with activities a) reduced-tillage rotation experiment, b) new crops for organic no-till, c) white mold suppression experiment. Major activities completed: Our 2-year project (32 no-till and 8 tilled cash crop sequences) to develop organic no-till crop sequences was completed, with a trial for winter and summer cash crops. Across all summer cash crop treatments, we also established microplots with supplemental weeding and fertility. The second year of the white mold study evaluated the effect of cereal rye biomass on both white mold suppression and performance of three main crops: dry bean, soybean, and sunflower at the Geneva NY research station. Data Collected: We assessed weed suppression, crop establishment and crop yield in differing cover crop mulches. For the white mold study we collected crop yield and biomass and weed biomass. Results: Winter cash crops struggled to emerge through high biomass mulches. Summer cash crop emergence was relatively unaffected by mulch biomass, and the high biomass mulches suppressed the most weeds. Across all treatments, no-till yields were comparable to the tilled control in at least one cover crop mulch. Results are forthcoming from the white mold trial. Key outcomes: By comparing the cover crop mulches to the tilled control, we described the potential of each no-till crop sequence. Having a more diverse set of cash crops that can be grown using organic no-till methods is an important step towards longer durations without tillage and a transition to continuous organic no-till crop production. Using cereal rye mulch for soybean, sunflower, and drybean is

promising as a long-term potential solution for reducing white mold in no-till and organic production systems. Objective 3 included a series of research trials to improve decision making in organic no-till soybean. Major activities completed: To help inform fertilizer requirements for the decision support tools, an experiment with roll-down soybean and three starter fertilizer treatments was repeated at the Musgrave Research Farm (NY) and the Arlington Agricultural Research Station (WI). Poultry litter (5-4-3), feather meal (8-2-2), and sodium nitrate (15-0-2) treatments were compared to a control with no fertilizer. To guide decision making around no-till soybean planting options, an experiment examined alternatives to planting soybeans at anthesis using two different triticale termination methods. Treatments were 1) Triticale forage harvested at boot stage, 2) triticale terminated with a roller crimper at anthesis, 3) no-cover crop control. Soybeans were planted in all treatments at triticale boot stage in late May. Data Collected: For the fertilizer study, cover crop biomass, soybean growth stage, stand counts, height, leaf greenness and yield, and weed biomass were measured. For the triticale study, weed prevalence, soybean development, and soybean grain yield were collected. Results: Neither starter fertilizer application nor source of fertility resulted in a significant difference in plant stand, soybean biomass, or soybean grain yield. In the triticale experiment, the forage harvested treatment had substantially higher weed pressure because ground cover was removed as compared to the roller crimped and cultivated control treatments. Key outcomes: Results from the fertilizer study suggest that using starter fertilizer for soybeans in rolled rye will not reliably offset the cost. This management consideration will be useful to include in our roll-down soybean decision support tools. For the triticale study, weed suppression was enhanced by roller crimping triticale at anthesis, although soybean plant stand was reduced due to the extended time in which soybeans grew underneath the standing triticale canopy. Objective 4 focused on outreach to facilitate farmer-to-farmer learning on organic no-till production. Major activities completed: We continued to distribute hard copies of the Organic No-till Soybean guide to farmers and researchers throughout the Northeast. The guide was posted on the Sustainable Cropping Systems website, as well as on the Hudson Valley Farm Hub website. An OGRAIN (Organic Grain Resources and Information Network) conference pre-event focused on farmer-to-farmer information sharing on January 27, 2022. The OGRAIN list serve continued to be a way for farmers to share organic no-till information and experiences. A farmer advisory board meeting was held for the project on February 18, 2022 with 18 participants. We are still working on the education modules, learning experiences, and international summit. The international summit is being planned for during the 2023 Agronomy Society of America meeting. Data Collected: NA Results: NA Key outcomes: A video on cover crops and cash crop sequences for organic no-till was posted on the Hudson Valley Farm Hub's website to introduce farmers to the experiment. Another video highlighted the inter-row mower, a novel tool for managing weeds in organic soybean systems, and reached 1.4 thousand views. Objective 5 focused on incorporating no-till crop production topics in undergraduate and graduate student curriculum. Major activities completed: A module about organic no-till was developed and delivered in PLSCS 3800 (Principles and Practices in Certified Organic Agricultural) at Cornell University. Students in PLSCI 4125/6125 (Cover Crops in Agroecosystems) at Cornell University learned about the relationship between crop seed size and emergence by conducting a greenhouse experiment and measuring seedling emergence across several planting depths. Data Collected: NA Results: NA Key outcomes: The greenhouse experiment in PLSCI 4125/6125 was shared with other educators and conducted at six universities. In the course at Cornell, students learned about the history of organic agriculture, the USDA National Organic Program, management practices used in organic crop and livestock production, and scientific research on organic agriculture. Laboratory sessions complemented lecture discussions with fieldwork and trips to a variety of organic farms. **Publications** - Type: Journal Articles Status: Published Year Published: 2022 Citation: Menalled UD, Adeux G, Cordeau S, Smith RG, Mirsky SB, Ryan MR. 2022. Cereal rye mulch biomass and crop density affect weed suppression and community assembly in no-till planted soybean. Ecosphere 13(6): e4147. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Ryan, MR. 2021. Crops better when grown together. Nature Sustainability 4:926-927. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Menalled, UD, MR Ryan, and SJ Pethybridge. January 5, 2021. Organic no-till soybean seeding rate and nitrogen fertilization effects on weed suppression. Proceedings of the Northeastern Plant, Pest, and Soils Conference. 75:89. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Pelzer, CJ, S Wayman, J Cagle, U Menalled, CA Peterson, TJ Rose, and MR Ryan. November 8, 2021. Rolled-Crimped Summer-Sown Cover Crops for No-till Planted Organic Winter Wheat. ASA, CSSA, SSSA International Annual Meeting. https://scisoc.confex.com/scisoc/2021am/meetingapp.cgi/Paper/135466 **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience:Target audiences reached during this reporting period were organic farmers in the Upper Midwest and the Northeast regions who grow grain crops as well as forages, and who have struggled with decreased profitability over the past several years due to challenges stemming from extreme weather, pest outbreaks, or weaker markets. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project has offered four undergraduate student researchers an opportunity to learn about agriculture research within no-till organic systems. Two MS students and one PhD student managed field experiments related to this project. These students gained experience in study design, developing and refining protocols, and interfacing with stakeholders through demonstrations and

field days. Research technicians have gained experience in refining sampling protocols and methods, weed identification, and organic no-till management techniques. How have the results been disseminated to communities of interest? Results have been distributed through field days, farmer-advisory board meetings, scientific and farmer conferences, virtual conferences, and a no-till organic soybean growers guide. What do you plan to do during the next reporting period to accomplish the goals? Objective 1: The Self-Seeding Cereal Rye in Organic Soybean experiment will be initiated. The second year of data will be collected for the Supplemental Weed Management experiment. Data will be analyzed from the first year of work. Objective 2: The Reduced-tillage Rotation experiment will be implemented. New Crops for Organic No-till and the white mold experiment will be repeated for a second year. Data will be analyzed from the first year of work. Economic and labor analyses will be conducted. Objective 3: Plans will be discussed with farmers and on-farm trials will be initiated based on farmer interest. Rye growth data will be used to inform planning decision support tools. Objective 4: We will hire a new post-doc to lead these activities. The organic no-till soybean production guide will continue to be disseminated. Preliminary data from experiments will be shared at a winter farmer meeting. We will meet with our project advisory board in February 2022. Objective 5: Experiential learning activities will be tested, undergraduate course modules will be planned and tested. **Impacts** What was accomplished under these goals? Objective 1. 1. Although this experiment has not yet been implemented, a YardMax Power Sweeper was used for a proof-of-concept test to explore promoting self-seeding in a cereal rye cover crop. The goal of using the power sweeper was to dislodge the cereal rye seed heads from the cover crop and promote a second cereal rye cover crop through self-seeding. 2. Visual observation of performance of power sweeper in cereal rye mulch. 3. We observed that the power sweeper dislodged seeds from cereal rye seed heads. No difference between brush angles was seen. 4. Working with the power sweeper is a step towards understanding if self-seeding can be promoted for the roll-down organic soybean system. Little information exists about what can be used to promote self-seeding of cereal rye mulch after roller-crimping. Activity 1b. 1. In September 2020, the supplemental weed management study was initiated at the Musgrave research farm in Aurora, NY. Nine treatments in the experiment featured high soybean seeding rates, inter-row mowing, weed zapping, and combinations of these treatments compared against a no-management control. Cereal rye was planted for upcoming experiments in 2022. 2. Cereal rye and weed species biomass, soybean biomass, and soybean yield and density were collected. 3. Nothing to report. 4. Concerns about sole reliance on cover crop mulch for weed suppression and the inability to manage weeds, especially if cereal rye biomass production is low, has been cited by farmers as a critical limitation preventing greater adoption of organic no-till soybean. This research will provide important insight into the role of specialized weed-management equipment to help address this limitation. Objective 2. Activity 2a. No accomplishments for this reporting period. Activity 2b. 1. A field experiment testing the efficacy of various rotations for organic no-till was implemented at two sites, the Musgrave Research Farm and the Hudson Valley Farm Hub (Hurley, NY). 2. Weed communities, and crop biomass and yield were sampled. Crop pests were monitored, and crop roots were assessed to study crop disease. 3. Preliminary analysis of cover crop biomass showed that cereal rye produced the most biomass and hairy vetch the least biomass. Weed biomass was lowered by cover crop biomass with an exponential reduction in weed biomass around 2,500 and 5,000 lbs/ac of cover crop biomass. Weed community analysis suggests that cover crop species affect weed community composition. 4. The goal of this work is to give farmers more flexibility when designing no-till crop rotations, facilitating the adoption of organic no-till. Activity 2c. 1. The white mold study was initiated to evaluate the effect of cereal rye biomass on both white mold suppression and performance of three main crops: dry bean, soybean, and sunflower at the Geneva NY research station in fall 2021. Treatments were two seeding rates of rye and a bare-soil control, with sunflower, soybean, and dry bean. Next year, the plots will be inoculated with white mold sclerotia. A sister trial was initiated to explore trade-offs with black bean plant populations, weed infestations, and white mold, involving five black bean seeding rates ranging from 100,000 seeds/acre to 350,000 seeds/acre. 2. No data collection this reporting period. 3. NA 4. Using cereal rye mulch for soybean, sunflower, and drybean is promising as a long-term potential solution for reducing white mold in no-till and organic production systems. Exploring dry bean seeding rates in rolled-crimped cereal rye mulch is important because performance may be enhanced by increasing the seeding rate in no-till cereal rye, similar to what has been quantified in soybean. Objective 3. 1. To help inform fertilizer requirements for the decision support tools, an experiment with roll-down soybean and three starter fertilizer treatments was initiated at the Musgrave Research Farm (NY) in June 2020 and replicated at the Arlington Research Farm (WI) and Musgrave Farm in 2021. Poultry litter (5-4-3), feather meal (8-2-2), and sodium nitrate (15-0-2) treatments were compared to a control with no fertilizer. A soybean seeding depth experiment was replicated at the Musgrave (2019 and 2020) and Arlington (2021) research farms with five seeding depth treatments ranging from 0.25 inches to 3.25 inches deep. Cereal rye was established at a collaborating field site, the Hudson Valley Farm Hub, for a dry bean seeding rate trial into rolled rye for 2022. 2. Data collection included cover crop biomass, soybean growth stage, stand counts, height, leaf greenness and yield, and weed biomass. 3. Preliminary results suggest there were no significant differences in soybean biomass, stand counts, or yields between fertilizer treatments. For the seeding depth study, in 2020 (a dry year), soybeans planted at deeper depths had higher plant density and soybean grain yield, whereas in 2019 (a normal

moisture year) there was no influence of seeding depth on soybean grain yield. 4. Our results suggest that using starter fertilizer for soybeans in rolled rye will not offset the cost. Given our seeding depth results, we concluded that the no-till rolldown soybean system does not do well in dry years, likely due to a lack of good seed-to-soil contact. However, increased soil moisture in wet years improves seed-to-soil contact. This management consideration will be useful to include in our roll-down soybean decision support tools. Good planting equipment to achieve sufficient depth is important for the success of the system in dry years. Objective 4. 1. \"Organic No-Till Planted Soybean Production: A guide for organic farmers in New York State\" was printed and 297 copies were distributed to farmers, extension educators, and researchers in NY and WI. To create content for extension tools and farmer education events, work was begun on an APSIM (Agricultural Production Systems sIMulator) model to explore questions on no-till soybean yield gaps. Early work involved configuring APSIM for the conditions and management practices at the Musgrave Research Farm and running simulations with soybean yields and soil moisture in tilled/no-till treatments. 2. Data from multiple previous experiments on cereal rye biomass and soybean yield were collated and cleaned. 3. Work will continue when a new post-doc has been hired for the team. 4. Results from the APSIM model will help inform management standards for cover crop and soil moisture management. Objective 5. 1. A farmer-advisor board meeting was held in April 2021 to develop relationships with our farmers and collaborators. The meeting included research updates from organic no-till experiments in NY, PA, and WI, in addition to receiving feedback on our Organic No-Till Soybean Guide for NY, exploring ways farmers can engage in research trials, and discussing support tools for no-till. On Sept 13, 2021, an on-farm meeting was held with two members of our farmer-advisory board. The farmer's brainstormed ideas about reduced-till rotation management that included inter-row mowing, strip tillage in corn, trade-offs of harvesting summer annuals vs. returning the crop to the soil, and ways to improve buckwheat biomass production. We are currently planning another advisory board meeting for February 2022. 2. NA 3. NA 4. Building relationships with our farmer advisors will help us better develop modules and learning activities for the future. **Publications** - Type: Journal Articles Status: Published Year Published: 2021 Citation: Wallace, JM, ME Barbercheck, WS Curran, CL Keene, SB Mirsky, MR Ryan, M VanGessel. 2021. Cover crop-based, rotational no-till (CCORNT) management tactics influence crop performance in organic transition within the Mid-Atlantic U.S. Agronomy Journal 113: 53355347. - Type: Journal Articles Status: Published Year Published: 2021 Citation: 10. Menalled, UD, SJ Pethybridge, CJ Pelzer, RG Smith, A DiTommaso, and MR Ryan. 2021. High seeding rates and low soil nitrogen environments optimize weed suppression and profitability in organic no-till planted soybean. Frontiers in Agronomy 3:678567. - Type: Journal Articles Status: Published Year Published: 2021 Citation: MR Ryan, S Wayman, CJ Pelzer, CA Peterson, UD Menalled, and TJ Rose. 2021. Winter wheat (Triticum aestivum L.) tolerance to mulch. Plants 10:2047. - Type: Books Status: Published Year Published: 2021 Citation: Ryan, MR, BA Caldwell, K Crowley, JA Liebert, U Menalled, CJ Pelzer, L Pickard, and S Wayman. 2021. Organic No-Till Planted Soybean Production. Sustainable Cropping Systems Lab. Cornell University, Ithaca, NY. https://bit.ly/ontsguide - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Menalled, U., M.R. Ryan, S. Pethybridge. Organic no-till soybean seeding rate and nitrogen fertilization effects on weed suppression. ASA, CSSA & SSSA International Annual Meeting. ASA Section: Agronomic Production Systems. Virtual event, Nov. 9-13, 2020. 126271. ** **

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Value-added Grains for Local and Regional Food Systems

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Project No.	NYC-149577
Agency	NIFA NY.C\
Project Type	OTHER GRANTS
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Investigator(s)	Sorrells, M.; Darby, HE, MA.; Mallory, EL, .; Selman, LA, .; Rutkoski, JE, .; Dawson, JU, C.; Gutierrez, LU, .; Malacarne, JO, .

NON-TECHNICAL SUMMARY

Diversity is essential to sustainability of organic farms, to improve and maintain soil health, manage diseases and pests, and sustain whole-farm economic viability in spite of climate change and market instability. However, the need for an adequate return per acre has worked against diversity on many organic farms, leading to shortened and simplified rotations on vegetable farms that often precludes crop rotation and sufficient use of cover crops. This project will add value and knowledge in the production and marketing of specialty food grain crops to improve farm economics with the goals of increasing their utilization and enhancing the biodiversity and sustainability of organic farms. The long-term goal of this multi-region, integrative project is to provide organic growers, processors and consumers with new knowledge about food grains that will lead to economically rewarding and sustainable organic farms. Specifically, the objectives for this project are to:1)Evaluate germplasm and develop new varieties of small grains with high market value including food quality wheat, emmer, spelt, einkorn, naked barley, rye and naked oats for desirable grain processing, culinary characteristics and nutritional quality.2)Optimize grain quality by synthesizing best management practices for seed production, disease control, planting, harvest, cleaning, and storage that are cost-effective and appropriate for organic production.3)Assess and increase opportunities for local and regional organic grain market demand, aggregation, and distribution.4) Develop an outreach program that connects key stakeholders in organic grains supply systems to each other and with the resources they need. This project will substantially increase the number of varieties of wheat and other small grains with high market potential available to organic farmers and will characterize varieties of wheat for milling and baking quality, sensory and flavor components and nutritional value. This study will compare several different varieties grown in multiple environments so we can accurately assess varietal differences for their response in a target set of environments. Methods for alleviating two critical production issues for enhancing organic winter grains winter survival and seed-borne disease control will be evaluated. This project will deliver a comprehensive assessment of the demand for organic grains by individual and institutional consumers as well as value-chain mapping and supply-side analysis. A key component is the nutritional value of local organic grains and this project will deliver the necessary data and make it publicly available in the USDA FoodData database. The outreach program described in Objective 4 represents a comprehensive plan for connecting stakeholders with each other and the informational resources for the success of this project.

OBJECTIVES

The objectives for this project are to:1) Evaluate germplasm and develop new varieties of small grain crops with high market value including food quality wheat, emmer, spelt, einkorn, naked barley, rye and naked oats for adaptability to organic systems and for desirable grain, processing, culinary characteristics and nutritional quality.2) Address two critical production issues for organic value-added grains: winter survival and disease-free seeds.3) Assess and increase opportunities for local and regional organic grain market demand, aggregation, and distribution.4) Develop a comprehensive outreach program that connects key stakeholders in organic grains supply systems to each other and with the resources they need.

APPROACH

1.1 Germplasm Evaluation:In each year of the project, germplasm will be evaluated at multiple locations: on certified organic land. Germplasm will be accessed from a wide variety of sources, including the Cornell wheat collection, the National Small Grains Collection, organic seedsmen in western Canada and Ontario, organic farming groups in the Maritime provinces and Quebec, the Ohio and Montana Seed Foundations, North Carolina State University, the Daisy Flour Mill, North Dakota State University and the French National Institute for Agricultural Research (INRA.1.2 Evaluations by Farmers:A selection of the highest performing entries from the advanced organic breeding lines will be evaluated for yield and baking quality on five farmers\' fields in Wisconsin, Illinois, Maine and Vermont in large strip-plots with three replications over two years.1.3 Evaluations by Bakers:Each region will conduct four quality evaluation trials with artisanal bakers. Evaluations will be conducted in Vermont, Maine, NYC and Upstate NY for the Northeast, and in Minneapolis, Madison (2) and Chicago for the Midwest. Artisan bakers will host evaluations and have experience with evaluating local grain varieties. Sensory evaluation will be done at UVM (see next section) and with chefs connected to GrowNYC. GrowNYC will conduct outreach to bakers, millers and farmers in the Northeast Region. For Midwest baking trials, grain will be milled at Madison Sourdough bakery. Andrew Hutchison = will host an evaluation in Madison in the first two years of this project.1.4 Sensory Evaluations:In phase 1, the UVM trained descriptive sensory panel, under the direction of Roy Desrochers will screen a set of cooked grains representing a range of wheat and rye varieties from multiple geographic locations. We will then use this information and work with the bakers to produce a set of wheat and rye baked sourdough bread with a wide range of aroma and flavor. In phase 2, we will use the aroma and flavor information from phase 1 to select a sub-set of 12 wheat and rye variety sourdough breads to use in central location testing with target users. A standard hedonic method (overall liking, 9-point degrees of liking scale) will be employed to test approximately 100 potential users with these value-added baked goods.2.1Enhance Winter Grain Survival:On-Farm Winter Grain Survival Survey:In years 1 and 2, Maine and Vermont will each follow 10-12 winter rye or wheat fields per year from planting through harvest and collect site, management, and climatic information that may help explain winter survival. The survey will focus on a ≤ 5-acre area in each field. One composite soil sample from each field will be submitted for a standard soil test.In years 2 and 3, project staff will assist participating farmers who want to test winter survival management strategies that they identified as promising either from our survey or elsewhere.2.2Improve Seed-borne Disease Management:This project will develop a systems approach that combines multiple organic methods to manage seed- borne diseases in organic small grain seed production. Two seed lots each of wheat, barley, and oats with known infection of primary seed-borne diseases will be used. Infection by seed-borne disease will be quantified using standard International Seed Testing Association (ISTA) (ISTA, 2014) protocols, and include loose smut, common bunt, FHB, barley leaf stripe and glume blotch.3.1:Quantify Demand and Consumer Preferences:This project will study current perceptions of specialty organic grains among individual and institutional consumers using surveys to generate insight into the market potential of organic small grains and identify barriers to market growth. The surveys will use economic choice experiments to collect rigorous data on the role of price and product attributes on consumer demand. The City University of New York\'s Urban Food Policy Institute will be engaged to provide support on the survey mechanisms.3.2:Nutritional Value of Local Grain Products:Nutritional analyses will be completed for the three currently most popular organic products from local mills (stoneground whole wheat flour, 100% whole grain; stoneground sifted wheat flour, 86% extraction; dry-rolled oats), as well as an emerging organic grain product, naked barley. Samples of these products will be submitted to Eurofins Nutritional Analysis Center (Des Moines, Iowa) for analysis of parameters for a standard nutritional label (calories, protein, fat, ash, sugars, total dietary fiber, calcium iron, potassium, and folate) plus B-6, magnesium, and essential trace elements.3.3:Value Chain Mapping and Supply-side Analysis:This project will map the value chain surrounding organic grain production, processing, and transportation. We will identify the cost shares of production, processing, value-added, and transportation in the final cost of organic grain products sold to consumers.4.1 Fact Sheets, Research Reports, and Webinars:In years 2 and 3, Alice Formiga will conduct webinars to be publicized in the eOrganic newsletter. Webinar recordings will be available at the eOrganic website and YouTube channel, and linked to the eXtension Learn website.4.2Marketing and Educational Materials:These materials will be based on the results of the surveys in Objective 3. Co-PD Selman ofCulinary Breeding Network(CBN) will lead and work with Co-PDs Russell of GrowNYC, Dawson andSeed to Kitchen

Collaborativeand Hartman of Artisan Grain Collaborative to (1) develop marketing materials for the public, chefs and institutional users; (2) create a consumer-focused grain marketing website including project summary, grain descriptions, nutritional information and recipes; and (3) design overall project branding including artwork and design. The marketing materials will be distributed regionally at farmers\' markets, producer meetings and conferences.4.3Conferences, Field Days, and Tastings:Project collaborators will host or attend several dozen conferences, workshops, field days and food events per year that bring together stakeholders from across the value chain. These include the annual Maine Grain Conference, Northern Grain Growers Conference, NOFA-NY Winter Conference, and MOSES Organic Farming Conference. Collaborators will distribute marketing and educational materials and coordinate tastings of products made with varieties available from the project.4.4Variety ShowcaseEvents and Consumer Outreach:The Culinary Breeding Network (CBN) with Selman as lead will organize two Variety Showcase events: one in Madison, WI (year 2) and one in New York City (year 3 with GrowNYC) to raise awareness and facilitate stakeholder networking. Selman and Russell will also organize an Ancient Grains dinner in NYC in year 3.4.5Market Access and Distribution:GrowNYC will continue to act as aggregator and seller of organic small grains from Northeast growers, that will include grains in development from this project for test marketing and garnering consumer feedback.4.6Social Media:Project announcements, activities and impact will be shared on social media through the Culinary Breeding Network (15K followers), GrowNYC Grains (3K followers), GrowNYC (\>130K), Artisan Grain Collaborative (2K followers), Seed to Kitchen (1K followers), eOrganic (5K followers) Instagram accounts, and University Extension social media outlets, including the NEEOGRAIN network. Progress 09/01/20 to 02/29/24 Outputs Target Audience:WI ·Producers ·End-users oProcessors oMillers oBrewers oDistillers oMaltsters oChefs oBakers ·Academic and industry researchers ·Organic organizations ·General Public oConsumers and farmers market shoppers oBusiness owners Artisan Grain Collaborative (AGC) staff worked through Renewing the Countryside (RTC) and with other project partners, especially UW-Madison colleagues, to connect stakeholders to project activities and develop resources. AGC communicated with our target audiences of farmers, processors, end-users and advocates through virtual and in-person events, trainings, conferences, and ongoing web-based communication. We reached organic farmers, crop advisors, and producers through field days and webinars, and end-users such as millers, brewers, distillers, maltsters, chefs, and bakers through planning for quality testing, remote quality tests, webinars, and a variety showcase. Graduate and undergraduate students were involved in field trials and quality testing. Through a variety showcase, we engaged other researchers, including ag professionals, plant breeders, and agronomists from academic, non-profit, and industry settings. Through this event, we connected breeders, farmers, and chefs with the public, showcasing varieties through chef-developed products. ME Malacarne Institutional food purchasers - Development of institutional food procurement survey and participation in Sodexo\'s \"The Maine Course\" local food procurement initiative. Northeastern Farmers interested in integrating organic ancient grains into their farm plans - Report on use if ancient grains and barriers to ancient grain procurement among institutional kitchens. Mallory The target audience for this project is current and aspiring organic grain farmers, processors, and end-users in New England, and the crop advisors and agricultural service providers who work with these businesses. Efforts to engage this audience included talks at the national, regional, and state level, consultations with individual farmers, and support of the Maine Grain Alliance. IL Organic farmers in Illinois and surrounding states NY We reached organic farmers, crop advisors, and producers through field days and webinars, and end-users such as millers, brewers, distillers, maltsters, chefs and bakers though planning for quality testing, webinars and remote quality tests. Graduate and undergraduate students were involved in the field trials and quality testing. We engaged other researchers including ag professionals, plant breeders, agronomists from academic, non-profit and industry settings through webinars and the grains week virtual conference. Through this virtual conference, we also engaged other organic organizations, consumers of local grains products and local businesses that could expand their use of local grains. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?ME The talks to farmer audiences listed under Products also included crop advisors and students. SDSU A M.S. student, Aastha Gautam, was supported by this project. She received training in plant breeding, oil chemistry and rancidity evaluation, and in conducting field trials under organic management. She received the 2022 Organic Crop Improvement Association (OCIA) Research & Education Graduate Scholarship. She presented her research project at the OCIA Annual Meeting in January 2023. IL This project enabled us to train a graduate student on how to conduct organic research trials and how to collect grain-quality data. VT Throughout the project duration technical staff received special training to carry out various lab analysis. Two technical staff were trained to learn lab protocols to evaluate cereal grain for seedborne diseases. This required training in the Bergstrom Lab at Cornell University. Two technical staff were trained to operate the steam oven. Both staff traveled to Alto Shaam headquarters in CT to receive a two-day training. WI This project is part of the training of Pablo Sandro, a Ph.D. student in the Plant Breeding and Plant Genetics graduate program at UW-Madison under the supervision of Dr. Lucia Gutierrez and Dr. Julie Dawson working on the development and selection of the winter wheat breeding population. University of Wisconsin-Madison, Organic Grains Field Day\-- Our Organic Grains Field Day provided education on the specific grain species and cultivars currently in

development for use in specialty food-grade markets. Additionally, we exposed new/emerging grain crops through showcasing work in Kernza. We had 30 attendees at the afternoon event, including several from out of state. Bake Trial Evaluations - As part of this grant\'s ongoing variety development work, we have engaged professional bakers and the public in evaluating breeding lines. Bakers rated the functional characteristics of doughs and their baking properties and visually assessed the resultant loaves. The public offered hedonic scoring of the varieties. Both groups learned more about plant breeding and variety development for regional and organic agriculture and how this can support regional food systems. AGCpartnered with UW-Madison on hosting bake trials that brought together and strengthened relationships between professional bakers in the region, AGC was able to leverage this grant for two specific training opportunities for the grain value chain in February 2024. First, we brought together a group of 13 stone millers for Northern Crops Institute\'s Stone Milling course. Stone millers are a critical aspect of regional grain supply chains and how grain gets from a farm to a consumer. This group of stakeholders is generally very under-resourced - this is the first time a group like this had come together for formal education that any of the participants were aware of. The group spent four days together at the training, a mix of classroom learning and discussion and hands-on demonstrations. The group benefitted immensely both from the knowledge grains and relationship development of spending a week amongst other stone millers who are working to advance processing capacity for regional grains. Second, we were able to support two folks in the region in attending the Bread Bakers Guild of America\'s annual conference, Camp Bread, and brining information about locally grown organic grains and stone milling to a broader baker community. NY Cornell All of our grad students receive training in plant breeding methods. Miranda Penny, is a second year grad student who oversees this Value-Added Grains research project. Glynwood: Professional Development for Bakers - Baking and Quality Evaluations of winter wheat varieties. Bakers received professional development opportunities by engaging with the research team and other baking professionals in the quality and functionality evaluation of two varieties of winter wheat developed through the arch of this project, first begun in 2011. Protocols for baking quality evaluations were developed and piloted with more than 24 bakers. These protocols can be used in future evaluations. Bakers gained a deeper understanding of the breeding process and factors that impact baking quality and functionality. A network of more than 24 professional bakers are connecting and sharing knowledge through project meetings, activities and direct interactions. Training and Technical Assistance for bakers and millers - GrowNYC and associate staff (2020-2022). The GrowNYC Grainstand team helped to incubate start-up bakeries that focused on using local flour by acting as a supply chain intervention, aggregating from producers and connecting directly to consumers. Staff provided technical assistance and troubleshooting for regular customers and more than two dozen professional bakers who then launched a commercial business. Several of these bakeries have since come to commercial scale: Knead Love Bakery, ACQ, LMNOP, Lost Bread, Sixteen Mill, Moonrise Bakehouse, Apt2Bread, and Mel the Bakery. Training and Technical Assistance for Growers - Glynwood Operations. Farm Store and Winter Grains and Staples CSA Add-on. (2022-23) Glynwood\'s Market Coordinator is a part-time position created with project support to develop market and outreach opportunities for items coming through this project in need of technical assistance and early-stage supply chain development and support. The Market Coordinator and Farm Store Manager worked together to create Standard Operating Procedures (SOPs) for Glynwood retail operations and a grain add-on for the established CSA program,catering to over 20 participants who received curated selections from our regional grain producers throughout the winter. Technical assistance for producers who are developing non-commodity products new to market. Provided 1:1 guidance on becoming market-ready, with regulatory compliance including: food safety, labeling, liability, and marketing to more than five local grain farms (Bound Brook Farm, Hudson Valley Hops & Grains, Carbon Sponge, Sun Runner Farm). NYS Local Chapter, Bread Bakers Guild of America. In August 2023, Glynwood partnered with the Bread Bakers Guild of America to launch the first local chapter of the BBGA. Collaborators created a survey for \"artisan bakers\'\' to learn more about barriers to procuring local grains. Fifteen commercial bakers attended the first meeting. Monthly meetings are now held. The group is identifying priorities they would like to focus on including how to source more and a greater variety of local and regional grains, professional skills development, and networking. How have the results been disseminated to communities of interest?ME This project was highlighted in all the presentations listed under Products. Research reports summarizing variety trial results were posted on our Extension website. SDSU The project was presented to organic farmers during farm tours of the Johnson\'s farm organized by Marble Seed and the Northern Plains Sustainable Agriculture Society (NPSAS) in July 2021, 2022, and 2023. The tour attendees came to visit the plots and information on cultivar performance was provided to them. We participated in the variety showcases in Madison, WI in 2022 and in Glynwood, NY in 2023 by setting up an oat display showcasing naked and hulled oat varieties and by providing information on oats to attendees. Both years, grain samples were sent to the bakers/chef to develop a recipe for the event attendees to sample. IL None VT The results of this project were disseminated through publications, presentations, educational and networking events, and a variety of other tools, research reports, and resources that were made available on our Extension websites. See \"Products\" and \"Other Products\" for a complete listing. WI UW-Madison\'s team has been working on building connections with the community and organizing a variety of showcases and field days. At the variety showcase event, bakers and chefs are paired with breeders

and their varieties to generate a unique recipe that showcases grain. The 2022 variety showcase was held in Madison, Wisconsin. As we were local, we were paired with two local artisanal bakers, Andrew Hutchison of Madison Sourdough and Kirk Smock of Origin Breads, to showcase the promissory experimental lines 47.04 and 260.06. The 2023 variety showcase was held in Cold Springs, NY. We were paired with Andrew Hutchison of Madison Sourdough to showcase the promissory experimental line 260.06. At the same time, the public could propose potential names to be used in the release of line 260.06 as a commercial new variety. This event allows the public to interact with the bakers/chefs and breeders and learn about the different aspects of the grains and breeding process. Results have been consistently delivered and shared in each growing season through field days and meetings with the public or interested parties. We expect to continue working on sharing information and releasing cultivars, which is the ultimate objective of product development and delivery to the community. Project results have been disseminated via AGC\'s newsletter, website, social media, and other listservs and newsletters of broader network and partner businesses, organizations, and institutions. UW Organic Grains Field Day - The grains field day was a participatory event where an overview of the breeding programs was presented, and the varieties being developed were shared directly with the participants of the field day. Promotion and advertising of the event occurred through various listservs targeting potentially interested stakeholders such as the OGRAIN network, the Artisan Grain Collaborative, and associated social media sites. Sensory Evaluation of Grains\--Preliminary results of sensory evaluation of experimental wheat cultivars were communicated to the participating bakers through post-activity group Zoom meetings, along with the timelines for potential release of any experimental lines they worked with. Ranking results were communicated with breeding programs and used to inform the advancement of the material in their programs. We have developed a sourdough-specific scoring sheet that the project team can use for ongoing sensory evaluation. Bake Trial Evaluations\--Preliminary functional results from bake trials were communicated to the participating bakers through post-activity group Zoom meetings, along with timelines for a potential release of any experimental lines they worked with. Ranking results were communicated to breeding programs and used to inform them of the advancement of the material in their programs. AGC regularly shared information about the project through our monthly newsletter, regular internal communications with our 220+ farmer, processor, end-user, and advocate members, and through targeted events such as field days, public bread tastings, virtual panel discussions, and in-person events and conferences. NY Results of our small grains breeding trials are disseminated via email, online web site, and by mail to over 300 stakeholders. Results are also provided at workshops and field days. Glynwood Direct communication with stakeholders by the PI, Market Coordinator, and Farm Store Manager. Participation in outreach events; Home Bakers Meetup, NOFA Farm Fest, Winter Market, Hudson Valley Value Added Grain School. Glynwood outreach channels. Fresh From Glynwood Newsletter,@glynwood (7596 followers) \@glywnoodfarmstore (967 followers), \@jrussell441(645 followers). GrowNYC outreach channels. - Website, Social Media \@grownycgrains (2020-2022) 2023.Times Union.Farm Program pushes small grains as next big thing. 2023.Morning AgClips.Tasting Event of the Year: 2023 Variety Showcase at Glynwood. 2023.Morning AgClips.Researchers Investigate the Promise of Food Procurement. 2023.Walden Mutual.Our Deep Dive into Regional Grains. 2023.Food Print.Eat more grains and keep it local. 2023.Food Print.The Movement to Revive Local Grains-and the Infrastructure Required to Keep it Going. 2023.Blue Dot Living.Spreading the Good Grain Word. 2022.Modern Farmer.The Best Alternative Grain Flours to Have in Your Pantry. 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 NY During the 2020-2023 seasons, we coordinated yield trials for the following small grains that were grown on certified organic farms at the indicated on-station locations. Soft Winter Wheat (8 entries): IL, ME, NY, WI, VT Hard Winter Wheat (18 entries): IL, ME, NY, WI, VT Winter Naked Barley (5 entries): IL, NY, WI Winter Spelt (9 entries): ME, NY, VT Winter Rye (10 entries): ME, NY, VT Winter Triticale (9 entries): ME, NY, VT Spring Wheat (18 entries): : ME, NY, SD, WI, VT Spring Naked Barley (5 entries): ME, NY, SD, WI, VT Spring Naked Oat (16 entries): IL, ME, NY, SD, WI, VT Spring Emmer (8 entries): ME, NY, SD, VT Free threshing spelt crosses were advanced and selections for free-threshing einkorn F4s were made. Free-threshing emmer selections were evaluated in a preliminary yield trial. IL We evaluated the agronomic performance of multiple varieties of soft red winter wheat and hard red winter wheat on an organic farm near Danforth, Illinois. Many of the soft red winter wheat lines from the University of Illinois performed well in our trials andone is being considered for variety release. We evaluated several laboratory-based grain quality traits on grain samples from organic trials in Danforth, IL, New York, and Maine. These traits are being assessed for their ability to predict artisan baking quality. WI On-farm evaluations of hard red winter wheat lines have been performed in collaboration with organic farmers to evaluate the performance of the elite lines on cultivar development and release.A crossing block including the most promissory lines have been developed in UW during 2021 and 2022. A total of 15 crosses have been obtained each season and F4 populations from these crosses were planted in the field for the 2023-2024 growing season. Artisanal baking evaluations of a set of 3 experimental lines and 2 checks were performed, including the participation of 41 professional bakers from states across the Northeast and the Midwest. The line 260.06 as being a top performer for artisanal baking. Based on this testing, line 260.06 has been selected for release. SDSU Variety development:Eleven SDSU naked oat breeding lines were entered

in the naked oat variety trial and 9 naked oats were tested across all 3 years. New populations were developed in Fall 2021 and Spring 2022. Five F2and F3naked oat populations were grown in the field in 2022 and 2023, respectively. A total of 14 breeding lines were selected and evaluated at 3 locations in 2023. In addition, we evaluated the level of rancidity development during the storage of naked oats. A subset of the genotypeswasevaluated for the development of rancidity during storage.The development of rancidity was evaluated at 3, 6, 9 and 12 months after harvest. Genotypes exhibited different fatty acid profiles and differed significantly for antioxidant activity, total phenolics and level of free fatty acids. Objective 2 VT We assessed the incidence of six seedborne pathogens in 85 samples of organic grains from 14 growers across midwestern and northeastern USA usingInternational Seed Testing Association protocols and molecular sequencing.We found infection frequencies ofBipolarisat 5.3%,Fusariumat 2.5%,Microdochiumat 3.1% ,Pyrenophoraat 2.5%,Parastagonosporaat 0.9%, andUstilagoat 2.9% within the 85 organic seed lots tested. Seed infections increased for three pathogens,Bipolaris, Fusarium and Pyrenophora, from 2021 to 2022 growing seasons likely due to seed-saving practices and increased total seasonal precipitation in Maine in non-steam treated grains, a location whereBipolarisfrequencies ranged from 47.5-60%.FusariumandPyrenophorainfections were highest in NY-VT seed lots ranging from 10-35% and one Minnesota rye sample at 11%. The University of Vermont Extension Northwest Crop and SoilsProgram conducted a trial consisting of three different aerated steam treatments to assess the efficacy of steam treatment in reducing the incidence of loose smut in spring barley. Seed which had been treated at 65 C for 5 minutes had the highest yield of 2839 lbs bu-1at 13.5% moisture content. The lowest smut incidence occurred in the seed which had been treated for 90 seconds at 75 C, a 20% reduction in the incidence of smut. ME A third year of a winter grain survival surveys were conducted in Maine. Seven fields on five farms were tracked from planting until harvest to identify the leading causes of winterkill and winter damage in New England. Most sites exhibited good overwinter survival. Snow mold was observed at two sites but did not affect stands or yields. Objective 3 WI AGC worked across the value chain with our farmer, processor, and end-user stakeholder community to better understand the challenges and opportunities for increasing the accessibility of all aspect of diversified grain production. Where these efforts stood out was in development of the food-grade grains track of The Land Connection\'s Organic Grain Conference which AGC hosted this year. Session topics included oat breeder updates with fellow project members, a session on beginning organic production, value-adding opportunities through malting, and growing grains on a small scale specifically for artisan bakers. ME The Maine Farmer\'s Market Price Report collected and disseminated agricultural prices during the 2023 market season to allows producers, to better understand price trends in the markets they serve. The technical report, \"The Use of and Interest in Ancient Grains in Northeastern Institutional Kitchens\" was produced. NY We have developed a survey targeted at institutional food buyers to betterquantifydemand andconsumerpreferences, including institutionalcharacteristics, procurement parameter,contracts, and incentive programs.Institutional food buyers/survey distribution plans in New York and New Englandare identified. AMeta-analysis of enterprise budgets for conventional/organic grain productionwill include a study of grain transportation costs and optimal siting for processing capacity.Glynwood assessed retail outlets, accessibility of products to consumers in NYC, Hudson Valley and held stakeholder meetings in the Hudson Valley CSA Network.Working with the GrowNYC Wholesale team, they developed wholesale strategies.Impact surveys were distributed to attendees. Objective 4 VT Sensory Summary A panel of trained tasters in the University of Vermont Extension assessed the sensory characteristics of artisan sourdough breads that were baked using varieties of winter wheat. In 2022 and 2023, bakers from King Arthur Baking Company and Red Hen Baking Company used flour milled from the winter grains, and a standard recipe and process, to bake test loaves of artisan bread that were submitted to the UVM trained panel for evaluation. The trained panel used a method called Profile Attribute Analysis to objectively assess the aroma, flavor, and texture of each bread sample. WI The University of Wisconsin held field days in the summers of 2021, 2022, and 2023, developed participatory baking trials in the springs of 2021, 2022, and 2023, and participated in the Variety showcases. AGC partnered with Judson & Moore Distillery in Chicago that uses locally grown organic grains in their products. OSU The Culinary Breeding Network organized Variety Showcases in each of the 4 years of the project. The project annual outreach event \"Variety Showcase\" occurred on October 11, 2023 - a one-of-a-kind event uniting plant breeders, seed growers, farmers, chefs, bakers, distillers, retailers, and all those who share a deep passion for the local food system. The event highlighted culinary grains, including wheat, rye, oats, barley, and corn. Over 200 attendees enjoyed 40+ tasting tables, each featuring a chef-prepared dish highlighting an important variety. Event sponsors included Milestone Mill, Maine Grains, Tokita Seeds, Johnny\'s Selected Seeds, High Mowing Organic Seeds and Walden Mutual Bank. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Mallory, E.B., H. Darby, E. Gallandt, and M. Sorrells. 2022. Organic wheat research in the Northeastern United States. Organic Management Systems Community Symposium Organic Wheat: Lessons Learned and Challenges Remaining. ASA-CSSA-SSSA International Annual Meetings, November 6-9, 2022, Baltimore, Maryland. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Darby, H. 2024. Growing Cereal Rye for Value-Add Markets. Hudson Valley Grain School, Kingston, NY. February 20, 2024. Type: Websites Status: Published Year Published: 2023 Citation:

Darby, H. and Emick, H. (2023). Steam Treatment to Reduce Ustilago spp. Infection in Spring Barley. University of Vermont Extension. Burlington, VT. accessed online at https://legacy.drup2.uvm.edu/sites/default/files/Northwest-Crops-and-Soils-Program/2023%20Research%20Rpts/2023SteamTreatmentFieldTrialReport_Final.pdf Type: Websites Status: Published Year Published: 2023 Citation: Darby, H., Bruce, J., and Brown, A. (2023). Spelt Variety Trial. University of Vermont Extension. Burlington, VT. accessed online at https://legacy.drup2.uvm.edu/sites/default/files/Northwest-Crops-and-Soils-Program/2023%20Research%20Rpts/2023_Spelt_Variety_Trial_Final.pdf Type: Websites Status: Published Year Published: 2023 Citation: Darby, H., Bruce, J., and Emick, H. (2023). Organic Winter Wheat Variety Trial. University of Vermont Extension. Burlington, VT. accessed online at https://legacy.drup2.uvm.edu/sites/default/files/Northwest-Crops-and-Soils-Program/2023%20Research%20Rpts/2023_OrganicWinterWheatVarietyTrial.pdf Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Gutierrez, L., 2023. Recent developments in the use of genomic tools in breeding. Invited speaker at the Natural Resource Institute (LUKE) of Finland. May 3, 2023. Jokioinen, Finland. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Gutierrez, L. 2023. Genomic selection in cereals: what to do with genotype by environment interaction? Invited speaker at the National Research Institute for Agriculture, Food and the Environment (INRAe) of France. June 1, 2023. Clermont-Ferrand, France. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Gutierrez, L. 2023. Genomic selection in cereals: from genes to satellites. Invited speaker at the Norwegian University of Life Sciences (NMBU) of Norway. May 25, 2023. ås, Norway. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Gutierrez, L., 2024. Optimizing resources for genotypic evaluations: sparse testing for genotype-by-environment interaction modeling. February 12-14, 2024. St. Louis, MO, USA. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Gutierrez, L., 2023. Perspectives on Predicting GxExM in cereals. GxExM Symposium II organized by the University of Florida. November 6-7, 2023. Gainesville, FL, USA. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Gutierrez, L., 2023. UW-Madison Cereals Breeding program update. WCIA annual meeting. November 28, 2023. Wisconsin Dells, WI, USA. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Gutierrez, L., 2023. Applications of Quantitative Genetics. Applications of Quantitative Genetics Symposium. November 4, 2023. UW-Madison, Madison, WI, USA. Type: Other Status: Published Year Published: 2023 Citation: Gutierrez, L., 2023. Genomic selection in cereals for sustainable cropping systems. Latins in STEM. October 5, 2023. UW-Madison, Madison, WI, USA. Type: Websites Status: Published Year Published: 2023 Citation: Williams, K., Tautges, N., Mirsky, S., Hartman, A. and Dawson J.C. 2023. The new growers guide to producing organic food grade grains in the Upper Midwest. UW Madison Extension Emerging Crops Initiative, Organic Grain Resources and Information Network, Michael Fields Agricultural Institute and Artisan Grain Collaborative. Available online at https://www.graincollaborative.com/ourwork and https://www.emergingcropswi.org/food-grade-grains.html Type: Journal Articles Status: Published Year Published: 2023 Citation: Massman, C., B. Meints, J. Hernandez, K. Kunze, K.P. Smith, M.E. Sorrells, P.M. Hayes, and L. Gutierrez. 2023. Genomic prediction of threshability in naked barley. Crop Science 63: 674 689. https://doi.org/10.1002/csc2.20907. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Born, Bred, and Brewed in New York: Breeding Preharvest Sprouting Resistant Barley with Good Malting Quality - Plant & Animal Genome Meeting San Diego Invited January 17. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Born, Bred, and Brewed in New York: Breeding Preharvest Sprouting Resistant Barley with Good Malting Quality Craft Malt Conference Portland ME, Invited March 18. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Value Added Grains for Local and Regional Food Systems USDA/OREI Project Directors Meeting - Washington DC, Invited April 19 Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Plant Breeding in the 21st Century: Molecular Breeding and High Throughput Phenotyping Syngenta Breeding Analytics Seminar Series. Invited October 26. Type: Journal Articles Status: Accepted Year Published: 2024 Citation: Sandro P, Bhatta M, Bower A, Carlson S, Jannink J.L., Waring D.J., Birkett C, Smith K, Wiersma J, Caffe M, Kleinjan J, McMullen M.S., English L, Gutierrez L*. 2024. Genomic prediction for targeted populations of environments in oat (Avena sativa L.). Crop & Pasture Science. Accepted (December 2023). Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Gautam, A. Krishnan, P., Sorrells, M., Caffe, M. 2023. Evaluation of Rancidity Development in naked oat genotypes during storage. Nebraska Plant Science Symposium. Lincoln, NE. April 25th. Type: Other Status: Published Year Published: 2023 Citation: Showcasing the Univ. of IL and Cornell organic wheat breeding programs at the Variety Showcase organized by Glynwood New York. October 16, 2023. Cold Spring, NY. Type: Other Status: Published Year Published: 2023 Citation: Small Grains Varieties for NY Seed Growers Field Day, Ithaca, NY June 30 Progress 09/01/22 to 08/31/23 Outputs Target Audience:We reached organic farmers, crop advisors, and producers through field days and webinars, and end-users such as millers, brewers, distillers, maltsters, chefs, and bakers though planning for quality testing, remote quality tests,

webinars, and a variety showcase. Graduate and undergraduate students were involved in the field trials and quality testing. We engaged other researchers including ag professionals, plant breeders, agronomists from academic, non-profit and industry settings through a variety showcase. Through this event, we connected breeders, farmers, and chefs with the public showcasing varieties through the products developed by chefs. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Gradate students were trained under this project at Cornell, Wisconsin, SDSUand Illinois. A M.S. student, Aastha Gautam, was supported by this project. She received training in plant breeding, oil chemistry and rancidity evaluation, and in conducting field trials under organic management. She received the 2022 Organic Crop Improvement Association (OCIA) Research & Education Graduate Scholarship. Miranda Penney is a grad student supported by this project at Cornell. She is organizing and analyzing data fromt the grains trials at collaborators\' locations. She is also developing free-threshing emmer, einkorn and spelt. UW: This project is part of the training of Ms. Ing. Agr. Pablo Sandro who is a Ph.D. student in the Plant Breeding and Plant Genetics graduate program at UW-Madison under the supervision of Drs. Lucia Gutierrez and Julie Dawson working on the development and selection of the winter wheat breeding population. Bake Trial Evaluations - As part of the ongoing variety development work through this grant, we have engaged professional bakers and the public in evaluation of breeding lines. Bakers rated the functional characteristics of doughs, their baking properties and provided visual assessment of the resultant loaves. The public provided hedonic scoring of the varieties. Both groups were able to learn more about plant breeding and variety development for regional and organic agriculture, and how this can support regional food systems. How have the results been disseminated to communities of interest?UW, AGC: UW-Madison\'s team has been working on building connections with the community, and organizing a variety of showcases, and field days.At the variety showcase event bakers and chefs have been paired with breeders and their varieties to generate a unique recipe showcasing the grain. This fall, Madison Sourdough prepared bread from breeding line 260.06 for the variety showcase in Cold Springs, NY. This event allows the public to interact with the bakers/chefs and breeders and learn about the different aspects of the grains and breeding process. The public was able to propose potential names for the new variety. Results have been delivered and shared in field days and meetings with the public or interested parties. We expect to continue working on sharing information and releasing cultivars, which is the ultimate objective of product development and delivery to the community. Project results have been disseminated via AGC\'s newsletter, website, social media, and other listservs and newsletters of broader network and partner businesses, organizations, and institutions. UW Organic Grains Field Day - The grains field day was a participatory event where an overview of the breeding programs was presented, and the varieties being developed were shared directly with the participants of the field day. Promotion and advertising of the event occurred through various listservs targeting potentially interested stakeholders such as the OGRAIN network and the Artisan Grain Collaborative, as well as associated social media sites. Sensory Evaluation of Grains - Preliminary results of sensory evaluation of experimental wheat cultivars were communicated to the participating bakers through post-activity group Zoom meetings, along with the timelines for potential release of any experimental lines they worked with. Ranking results were communicated with breeding programs and used to inform the advancement of the material in their program. We have developed a sourdough-specific scoring sheet that can be used for ongoing sensory evaluation by the project team. Bake Trial Evaluations - Preliminary results of functionality via bake trials were communicated to the participating bakers through post-activity group Zoom meetings, along with timelines for potential release of any experimental lines they worked with. Ranking results were communicated with breeding programs and used to inform the advancement of the material in their program. SDSU: Field days: The project was presented to organic farmers during farm tours of the Johnson\'s farm organized by Marble Seed and the Northern Plains Sustainable Agriculture Society (NPSAS) in July 2021, 2022, and 2023. The tour attendees came to visit the plots and information on cultivar performance was provided to them. Variety showcase: We participated in the variety showcases in Madison, WI in 2022 and in Glynwood, NY in 2023 by setting up an oat display showcasing naked and hulled oat varieties and by providing information on oats to attendees. Both years, grain samples were sent to the bakers/chef to develop a recipe for the event attendees to sample. What do you plan to do during the next reporting period to accomplish the goals?This project is wrappng up and a final report will be submitted in February/March. Impacts What was accomplished under these goals? Obj 1 Variety Testing: During the 2022-2023season, yield trials for the following small grains were carried out on certified organic farms at the indicated on-station locations. Soft Winter Wheat (8 entries): IL, ME, NY, WI, VT Hard Winter Wheat (18 entries): IL, ME, NY, WI, VT Winter Naked Barley (5 entries): IL, NY, WI Winter Spelt (9 entries): ME, NY, VT Winter Rye (10 entries): ME, NY, VT Winter Triticale (9 entries): ME, NY, VT Spring Wheat (18 entries): : ME, NY, SD, WI, VT Spring Naked Barley (5 entries): ME, NY, SD, WI, VT Spring Naked Oat (16 entries): IL, ME, NY, SD, WI, VT Spring Emmer (8 entries): ME, NY, SD, VT Also, two on-farm trials composed of five elite lines and two commercial varieties of hard red winter wheat were grown in WI. ?Variety development: UW: A crossing block produced a total of new 15 crosses including promissory elite lines and cultivars with known sources of FHB resistance. The F1:2 seed has been planted in the greenhouse along with lines F3-F4 from crosses generated during the 2021-2022 season. NY:Free threshing spelt crosses were advanced and selections for free-threshing

einkorn F4s were made. Free-threshing emmer selections were evaluated in a preliminary yield trial and over two locations in a replicated trial. SDSU: Eleven SDSU naked oat breeding lines were entered in the naked oat variety trial and tested across multiple locations. A total of 9 naked oats were tested across all 3 years. Seed purification and increase plots (5ft by 100 ft) were grown in the three years of the project.. Quality and sensory evaluations: Artisanal baking evaluations of a set of 3 experimental lines and 2 checks were performed, including the participation of 40 professional bakers from states across the Northeast and the Midwest (see events). These trials identified line 260.06 (Rouge de Bordeaux x Warthog) as being a top performer for artisanal baking, with line 47.04 also being preferred. Based on this testing, line 260.06 has been selected for release, with line 47.04 a potential release later, and other lines will either go into a more specialty market or be dropped. In 2023, the third experimental line tested was perceived to have very distinct flavor characteristics, which caught the attention of some brewers participating in the sensory evaluation. Bakers felt that this line might be an asset for products that did not require the flour to have technical performance characteristics suitable to sourdough bread. Public taste tests confirmed the suitability of lines 260.06 and 47.04 from a consumer acceptance standpoint, and many comments were received relative to the flavor complexity being higher than that of the check varieties. Quality evaluations Included 41 professional bakers and several hundred taste testers. Planned in collaboration with June Russell for the Northeast. Illinois bake test. Host College of DuPage/Bootleg Batard, Melina Kelson Glen Ellyn, IL. April 10-11 Illinois public taste test. Host Judson and Moore Distillery. Chicago, IL. April 11. Minnesota bake test. Host Sun Street Breads, Solveig Tofte. Minneapolis, MN. March 20-21 Minnesota public taste test. Host Bang! Brewing. Minneapolis, MN. March 22 Vermont bake test. Host King Arthur Baking Company, Carrie Brisson. White River Junction, VT. March 20-21 Vermont sensory evaluation. Organized by Roy Desrochers. Univ. of Vermont. March 21. Wisconsin bake test. Host Origin Breads, Kirk Smock. Madison, WI. Feb 27-28 ?Wisconsin public taste test. Host Giant Jones Brewing, Jessica Jones. Madison, WI. Feb 29 New York bake test. Host Wide Awake Bakery, Stefan Senders. Trumansburg, NY. Feb 13-14 New York public taste test. Host Ecovillage. Ithaca, NY. Feb 15 SDSU evaluated the quality of the grain samples from the naked oat variety trials grown in SD. We collected data on kernel size, percentage of hull, and beta-glucan, protein and oil concentration using NIR. In addition, they carried out an experiment to evaluate the level of rancidity development during the storage of naked oats. Obj 3 UW: Foundation seed was produced during the season 2022-2023 by UW-foundation seed. This was planted at Meadowlark Organic under contract to produce certified seed. A PVP application is being prepared. NY: Six free-threshing emmers were advanced for potential variety release and seed increase blocks were planted and harvested. Obj 4: Outreach activities contined at all collaborators\' field days and extension workshops. Collaboratorsparticipated in the variety showcases in Madison, WI in 2022 and in Glynwood, NY in 2023 by setting up an display tables showcasing value added grains such as naked and hulled oat varieties and by providing information on grains to attendees. Both years, grain samples were sent to the bakers/chef to develop a recipe for the event attendees to sample. Publications Progress 09/01/21 to 08/31/22 Outputs Target Audience:UW:We reached organic farmers, crop advisors, and producers through field days and webinars, and end-users such as millers, brewers, distillers, maltsters, chefs, and bakers though planning for quality testing, remote quality tests, webinars, and a variety showcase. Graduate and undergraduate students were involved in the field trials and quality testing. We engaged other researchers including ag professionals, plant breeders, agronomists from academic, non-profit and industry settings through a variety showcase. Through this event, we connected breeders, farmers, and chefs with the public showcasing varieties through the products developed by chefs. Farm to Flavor: Hartman: The \"Farm to Flavor\"event took place in Madison, WI on August 21, 2022 and was our largest outreach event during the reporting period. It brought together plant breeders, farmers, chefs, bakers and beverage makers to present and discuss the project\'s plant breeding activities and provide general exposure of each project grain to the public. The four hour event was attended by over 300 people. The breeding programs represented were from University of Wisconsin-Madison, Oregon State University, University of Minnesota, University of California-Davis, Cornell University, University of Illinois, South Dakota State University, University of Vermont, Organic Seed Alliance, KC Tomato, CreativeBotanics, and Hazzard Free Farms, Frogsleap Farm.Farming and non-profit participants included Yowela?talih\^ Farm (Stoughton, WI), Meadowlark Organics & Community Mill (Ridgeway, WI), Glynwood Center for Regional Food and Farming (Cold Spring, NY) and Janie\'s Farm and Mill (Ashkum, IL).Culinary participants included Abra Berens, author ofGrist, Granor Farm (Three Oaks, MI), Kyle Knall, Birch Restaurant (Milwaukee, WI), Beth Dooley, author ofThe Perennial Kitchen,Bare Bones Cooking (Minneapolis, MI),Jessica & Erika Jones, Giant Jones Brewery (Madison, WI), Kirk Smock, ORIGIN Breads (Madison, WI), Andrew Hutchison, Madison Sourdough (Madison, WI), Nathan Duplayee, Exact Sciences (Madison, WI), Joe Kaplan, Perennial Pantry (Burnsville, MN), Yusuf Bin-Rella, TradeRoots (Madison, WI), Elena Terry, Wild Bearies (Wisconsin Dells, WI), Jonathan Correra, La Cosecha Tortilla Company (Madison, WI), Jonny Hunter, Underground Meats (Madison, WI), Eric Bennedict, University of Wisconsin (Madison, WI), Sean Fogarty, Food Fight Restaurant Group (Madison, WI), Jordyn Bunting, Food Innovation Center (Portland, OR), and John Mleziva,State Line Distillery (Madison, WI). Attendees were surveyed and reported the following: 93% reported they learned something or make a new connection at the event. 97% reported they intend to apply the knowledge they gained 100%

reported that after attending the event they will seek out more local grains 70% reported that after attending the event they know more about organic plant breeding UM: The target audience for this project is current and aspiring organic grain farmers, processors, and end-users in New England, and the crop advisors and agricultural service providers who work with these businesses. Efforts to engage this audience included talks at the national, regional, and state level, consultations with individual farmers, and support of the Maine Grain Alliance and the Northern Grainshed Alliance. The following target audiences were reached through activities related to Objectives 3.1 and 3.3 during the current reporting period: Producers of organic specialty grains - infrastructure needs surveys Agricultural policy makers - report on economic impact of expanding processing capacity in the State of Maine. IL:Organic farmers in Illinois and surrounding states GrowNYC, Glynwood Hartman: Audience for Grains Week is reported on inthis document, also linked below. We also specifically targeted a group of 5 Midwest bakers who conducted virtual variety evaluation for the project. Further, though it wasn\'t a planned component of the grant activities, AGC conducted a consumer-facing Grains Views and Habits survey during the grant period, gleaning data from 1000 respondents to accompany the formal survey work that began in Y1 of the project, led by GrowNYC / Glynwood. The results of our survey data are capturedhere. This work did not go through IRB and will not be included in the publication, but it can provide some additional color and comparison for the formal project results. IL:Organic farmers in Illinois and surrounding states Grains week audience: Farmers, ag professionals, plant breeders, agronomists and academics heard research updates, and learned about grain production for artisan breads, cereals for animal feeds, & brewing and distilling. Professionals, home bakers, and consumers got an inside look into grain quality, accessing specialty and small grains, and interacted with a community of passionate chefs, bakers, and grain-lovers. Brewers, distillers, and maltsters connected with industry professionals to get the latest information on using grains in value-added production, as well as getting access to specialty regional grains. Plant stewards, chefs, bakers and brewers discussed the possibilities for expanding local grains, and the importance of reciprocity and cultural competency. Target audiences includedprofessionals in the culinary and craft beverage sectors, consumers and farmers market shoppers, farmers, primary Processors (grain handlers, millerss, distilleries, peer organizations, not-for-profits, culinary educators, and agricultural extension agents. UVT We reached organic farmers, crop advisors, and other stakeholders through field days and webinars, and end-users such as millers, brewers, distillers, maltsters, chefs and bakers though planning for quality testing, webinars and remote quality tests. Graduate and undergraduate students were involved in the field trials and quality testing. We engaged other researchers includingag professionals, plant breeders, agronomistsfrom academic, non-profit and industry settings through webinars and the Farm to Flavor Event. Through this virtual conference, we also engaged other organic organizations, consumers of local grains products and local businesses that could expand their use of local grains. Agricultural policy makers and Institutional food purchasers were reached. Changes/Problems:No changes for all institutions except GrowNYC and Glynwood. Key staff changes: Glynwood was officially onboarded to the project as a partner organization in 2022 with June Russell as the PI. GrowNYC and Glynwood have split the project funds while the project aims remain the same. What opportunities for training and professional development has the project provided?NY:All of our grad students receive training in plant breeding methods.Specifically, grad student ,Miranda Penny, has just joined our project to oversee this Value-Added Grains research project. SDSU:M.S. student, Aastha Gautam, received training in plant breeding, oil chemistry and rancidity evaluation, and in conducting field trials under organic management. She received the 2022 Organic Crop Improvement Association (OCIA) Research & Education Graduate Scholarship. She will present results from her research project at the OCIA Annual Meeting next January. UM:The talks to farmer audiences also included crop advisors and students. IL:This project enabled us to train a graduate student on how to conduct organic research trials and how to collect grain-quality data. UW:This project is part of the training of Ms. Ing. Agr. Pablo Sandro who is a Ph.D. student in the Plant Breeding and Plant Genetics graduate program at UW-Madison under the supervision of Drs. Lucia Gutierrez and Julie Dawson working on the development of the winter wheat breeding population. Our University of Wisconsin Organic Grains Field Day provided education on the specific grain species and cultivars currently in development for use in specialty food-grade markets. Additionally, we provided exposure to new/emerging grain crops through showcasing work in Kernza. As part of the field day, we visited the USDA malt quality lab in Madison, and provided access for stakeholders to understand the process of malting and introduced how barley or other grains are assessed when being considered for use as malt in food or beverages. We had 25 attendees at the half-day long event. As part of the ongoing variety development work occurring at universities involved in this grant, we organized and hosted a sensory evaluation of sourdough bread in Wisconsin, Vermont, and New York. This day-long activity at each site was led by an expert in sensory evaluation of food products, Roy Desrochers of UVM. Stakeholders that attended included graduate students, local millers, bakers, and grain growers. Participants were trained in scientific approaches to sensory analysis, and we evaluated 4 different experimental winter wheat cultivars. We were able to define a set of sensory attributes that bakers deemed important to rating the quality of wheat for use in artisan sourdough bread and were able to rank/rate the relative suitability of 4 pre-release breeding lines based on flavor. Bake Trial Evaluations - As part of the ongoing variety development work occurring at universities involved in this grant, we organized 12 different bakeries into 3

regional teams across the Midwest and Northeast to bake sourdough bread using 4 different experimental Winter wheat cultivars compared against currently available varieties. Bakers rated the functional characteristics of doughs, their baking properties and provided visual assessment of the resultant loaves. We were able to rank/rate the relative suitability of 4 pre-release breeding lines based on functional characteristics. Glynwood:Participant training onDescriptive Sensory Analysis included professional engagement on evaluation of breeding lines and varieties. We facilitated discussion of techniques, common attributes that provided feedback from professional bakers to growers and research teams. Our cohort of bakers was expanded to include 15 professional bakers from across multiple regions. This peer group engaged in rigorous discussion on creating methods and techniques for the evaluation of regionally adapted wheat varieties andis developing a shared vocabulary. TheGlynwood Farm planted winter barley, perennial wheat for demonstration and staff edification.Food safety and FSMA compliance assistance was provided for small producers, farmers and primary processors. Glynwood\'s Hudson Valley Bakers Convening provided professional education on regional value chains and current research. Provided opportunities for professional networking. How have the results been disseminated to communities of interest?NY:Results of our small grains breeding trials are disseminatedvia email, online web site, and by mail to over 300 stakeholders.Results are also provided at workshops and field days. SDSU:The project was presented to stakeholders at the Ag Horizons Conference, Pierre, SD in Nov 2021, and results were shared with organic producers at two field days (Southeast Research Farm Field Day and Johnson\'s Farm Annual Field Day). UM: This project was highlighted in all the presentations listed under Products. Research reports summarizing variety trial results were posted on our Extension website. UW, AGC:UW-Madison\'s team has been working on building connections with the community, and organizing a variety of showcases, and field days.At the variety showcase event bakers and chefs have been paired with breeders and their varieties to generate a unique recipe showcasing the grain. Small plates of the dishes were offered to the public in a setting that allowed the public to interact with the bakers/chefs and breeders and learn about the different aspects of the grains and breeding process. Results have been delivered and shared in field days and meetings with the public or interested parties. We expect to continue working on sharing information and releasing cultivars which is the ultimate objective of product development and delivery to the community. Project results have been disseminated via AGC\'s newsletter, website, social media, and other listservs and newsletters of broader network and partner businesses, organizations, and institutions. The UW grains field day was a participatory event where an overview of the breeding programs was presented, and the varieties being developed were shared directly with the participants of the field day. Promotion and advertising of the event occurred through various listservs targeting potentially interested stakeholders such as the OGRAIN network and the Artisan Grain Collaborative, as well as associated social media sites. Preliminary results of sensory evaluation of experimental wheat cultivars were communicated to the participating bakers through post-activity group Zoom meetings, along with the timelines for potential release of any experimental lines they worked with. Ranking results were communicated with breeding programs and used to inform the advancement of the material in their program. We have developed a sourdough-specific scoring sheet that can be used for ongoing sensory evaluation by the project team. Preliminary results of bake trial evaluations were communicated to the participating bakers through post-activity group Zoom meetings, along with timelines for potential release of any experimental lines. Ranking results were communicated with breeding programs and used to inform the advancement of the material in their program. Glynwood:GlynwoodWebsite& Newsletters included Glynwood Newsletter5900 followers,Glynwood Fresh (Farm Store & CSA) 1600 followersandBlog Posts Social Media-Instagram@glynwood 6200 followers;@glynwoodfarmstore 468 followers Press-Modern Farmer:The Best Alternative Flours to havein Your Pantry. PresentationsincludedNOFA-NY,Craft Maltsters Guild,Hudson Valley Bakers Convening, NYC Mayor\'s Office of Food Policy,Culinary Institute of America,Sustainable Food Systems and food Business Classes What do you plan to do during the next reporting period to accomplish the goals?SDSU:We will repeat the evaluation of rancidity development during storage on naked oat samples harvested in 2022. We will also determine the impact of mechanical damage caused by dehulling on rancidity development for multiple genotypes. We will continue the development of new naked oat breeding lines and share results with organic producers at field days in South Dakota. NY:We will continue evaluating the spring and winter grains trials and selecting free-threshing emmer, einkorn and spelt. We are also planning to move the spring free-threshing trait into winter emmer and einkorn backgrounds. UM:Conduct a third year of variety trials and a third year of monitoring farmers\' winter grain field for the winter survival survey and write a research report summarizing the three years of data from Maine and Vermont. UW:We planted the winter trials for the growing season 2022-2023. We planted a training population for hard red winter wheat composed of 150 lines to increase it to 300 lines in the 2023-2024 growing season. The training population phenotypic information will be used to train a prediction model that would allow selecting lines from the F4:5 generations for planting in a 2023-2024 field experiment. We will incorporate high throughput phenotypic information on our phenotype pipeline that would allow us to increase the efficiency of the data collection. We will advance lines from crosses made during the 2020-2021 season to F4:5, where the lines would be genotyped, and the information used to train a genomic prediction model to select promissory lines to plant in the field in the 2023-2024 season. We will plant spring field

trials as planned in the spring of 2022. An on-farm field day with involved stakeholders is planned to discuss trial results from both on-farm and on-station. We will host an in-person bake test with advanced lines near commercialization. Data from the sensory evaluation of grains & bake trial evaluations will both be summarized and presented to participating bakers and breeding programs, by experimental line and/or check cultivar, so that they can build familiarity and determine preferences with respect to upcoming material in breeding pipelines. This will be done in conjunction with the next round of bake tests so there is an ongoing body of knowledge being built around new experimental material being developed that is framed by commercial check cultivars. UM:We will conductfarmer-driven research projects to improve winter survival and write a research report summarizing the results. We will evaluate the nutritional composition of flour produced by small scale mills (Objective 3.2) and write two fact sheets, one on winter survival of fall-planted grains and one on weed management of organic grains. We will present research program and results in symposium presentation at the ASA-SSSA-CSSA International Annual Meeting in Baltimore, Maryland. Glynwood:We will publish and promote the CUNY GrowNYC Grainstand Evaluation in order to disseminate the findings of this consumer survey. Currently we are developing a promotional strategy; blog piece, and presentation slides that will run in both GrowNYC and Glynwood newsletters and presentations. Quality Evaluations of promising breeding lines and varieties. Discussion with project partners has begun.Glynwood and GrowNYC will collaborate on strategies to develop the wholesale market, train and educate staff, and develop project materials.Events -may be determined by COVID, public health factors.Home Bakers 2023and theVariety Showcase are planned.Other activities includePilot retail pop-ups and CSA add-ons.Outreach will continue via conference and meeting participation, and through direct communications with producers and end users.Communications will use the Glynwood Newsletters and social media channels. Impacts What was accomplished under these goals? Objective 1 Variety Testing: During the 2021-2022 season, yield trials for the following small grains were carried out on certified organic farms at the indicated on-station locations. Soft Winter Wheat (8 entries): IL, ME, NY, WI, VT Hard Winter Wheat (18 entries): IL, ME, NY, WI, VT Winter Naked Barley (5 entries): IL, NY, WI Winter Spelt (9 entries): ME, NY, VT Winter Rye (10 entries): ME, NY, VT Winter Triticale (9 entries): ME, NY, VT Spring Wheat (18 entries): : ME, NY, SD, WI, VT Spring Naked Barley (5 entries): ME, NY, SD, WI, VT Spring Naked Oat (16 entries): IL, ME, NY, SD, WI, VT Spring Emmer (8 entries): ME, NY, SD, VT Also, two on-farm trials composed of five elite lines and two commercial varieties of hard red winter wheat were grown in WI. Variety development: UW:A crossing block produced a total of new 15 crosses including promissory elite lines and cultivars with known sources of FHB resistance. The F1:2 seed has been planted in the greenhouse along with lines F3-F4 from crosses generated during the 2021-2022 season. New York:Free threshing spelt crosses were advanced and selections for free-threshing einkorn F3s were made. Free-threshing emmer selections were evaluated in a preliminary yield trial and over two locations in a replicated trial. SDSU:Crosses were made in Fall 2021 and Spring 2022 to develop new naked oat populations. During Summer 2022, five F2naked oat populations were grown in the field and 61 new naked oat breeding lines (F5:6) were evaluated in Brookings, SD. Nine oat breeding lines were evaluated for the second year in the naked oat variety trials. Quality and sensory evaluations: UW: Artisanal baking evaluations of a set of 3 experimental lines and 2 checks were performed, including the participation of 12 bakers from states across the Northeast and the Midwest. SDSU: One month after harvest, 8 grain samples were evaluated for oil composition, antioxidant activity, and total phenolics. In addition, the development of rancidity was evaluated by conducting free fatty acid, hexanal and peroxidase tests at 1, 5, 9 and 13 months after harvest, and by evaluating oxidative stability using a Rancimat. Genotypes exhibited different fatty acid profiles and differed significantly for antioxidant activity, total phenolics and level of free fatty acids. The level of free fatty acid increased significantly after 13 months for all genotypes. UVT:In February/March of 2022, a sensory training was conducted to identify, and define key sensory attributes in aroma (smell), flavor (taste), and texture (product feel) of whole grain bread. The UVM Extension DSA panel developed aProfile Attribute Analysis (PAA)scoresheet to be used in the winter wheat bake trial. The winter wheat bake trial was held simultaneously in VT, NY, and WI in April 2022. The northeast baking trial included six samples of flour provided to two bakers that produced two loaves of bread from each of the six samples. All samples were provided fresh to the DSA panel for immediate evaluation using the bread specific PAA ballot. Results showed that the new experimental line 260.06 \'Rouge de Bordeaux\' x \'Warthog\') was the closest in sensory performance to the target Turkey Red samples. The bread baked with \'Warthog\', 47.04 - \'Maxine\' x \'Gua\', and ZCL - 140.05 - \'Warthog\' x \'Gua\' were rated as having the most complex aroma and taste. Glynwood:Facilitated discussion of techniques, common attributes that provided feedback to growers and research teams.A cohort of professional bakers expanded to include 15 professional bakers from across multiple regions.We coordinated the sensory training for 12 New York participants who attendedDescriptive Sensory Analysistraining with Roy Desrochers at Hartwick College.Glynwood coordinated the baking evaluation of breeding lines with four New York state bakeries and coordinated the sensory evaluation of breads made by two New York City based bakeries. Objective 2 Winter survival (UM, UVT): A second year of a winter grain survival surveys were conducted in Maine and Vermont collaborators. Nine fields on five farms in Maine and seven fields on four farms in Vermont were tracked from planting until harvest with the goal of identifying the leading causes of winterkill and winter damage in Northern New England. Most sites exhibited

good overwinter survival during this second year of the project, and where winterkill did occur it was due to frost heaving and icing. Disease evaluation (UVT): The organic seed disease survey was initiated in January of 2022. 44 samples were submitted by seed growers in the Northeast and Midwest. We have completed the International Seed Testing Assay ISTA-7-027 for detection of fungal pathogens,Pyrenophora teresandPyrenophora graminea. 17 out of the 44 samples tested positive forPyrenophora spp. We have completed the ISTA-7-022 Assay forMicrodochium spp.on PDA media in addition to scoring forBipolaris, Stagonospora, Fusarium and Pyrenophora.25.7% of grains did not have fungal infections and 59.8% of the grains had secondary infections by non-target fungi.We have tested a small subset of 6 samples via PCR and sequenced ITS loci for detection of loose smut of barley,Ustilago nudaandU. tritici.We optimized a workflow (ISTA-7-013a) for embryo extractions and microscopy for confirmation of seed-borne loose smut and scored 4 out of 44 samples of test embryos within a range of \~20-50% infected embryos. Objective 3 UM:We have developed a survey targeted at institutional food buyers to betterquantifydemand andconsumer preferences,including institutionalcharacteristics, procurement parameter,contracts, and incentive programs.Survey is doneand a set of institutional food buyers/survey distribution plan in New York and New Englandare identified. Inthe coming yearwe will runthesurvey instrument and distribution plan through IRB at University of Maine in September, put the survey in the field in October/Novemberand analyzeandreport in January/February. AMeta-analysis of enterprise budgetsis completefor conventional/organic grain productionand will include a study of grain transportation costs and optimal siting for processing capacity. A study of the gap in processing capacity that exists for organic grains in Maineindicates thatMainecouldsupport anestimated \$37 Million inadditionalgrain andoilseedmillingsales,based on thevalue ofgrainproduced on thestate\'sfarms. Glynwood:Assessed retail outlets, accessibility of products to consumers in NYC, Hudson Valley and held stakeholder meetings in the Hudson Valley CSA Network.Working with the GrowNYC Wholesale team, we developed wholesale strategies Objective 4 In addition to the many field days and workshops documented in \"Products\" and \"Other Products\", we held a \"Farm to Flavor\" event in Madison WI on August 21st.It brought together plant breeders, farmers, chefs, bakers and beverage makers to present and discuss plant breeding activities and provide exposure of each project grain to the public. The four hour event was attended by over 300 people. Twelve breeding programs and many culinary participants were represented. We presentedparticipatory breeding efforts by incorporating the opinion of farmers, bakers, and industry in the process of development of cultivars adapted to organic systems. We showcased our experimental lines 260.06 and 47.04 which are candidates for variety release. Attendees reported the following: 93% reported they learned something or make a new connection at the event. 97% reported they intend to apply the knowledge they gained 100% reported that after attending the event they will seek out more local grains 70% reported that after attending the event they know more about organic plant breeding Publications Type: Other Status: Published Year Published: 2022 Citation: June 2022 NYC Mayor\'s Office of Food Policy. Presentation: Regional Grains & Staples. Type: Other Status: Published Year Published: 2022 Citation: July 2022 Glynwood Farm Dinner featuring Regional Food Programs, Grains & Staples. Grains on the menu at this farm dinner, 75 people Type: Other Status: Published Year Published: 2022 Citation: October 2021 Grains at Glynwood ? Created a grain bed adjacent to the Glynwood CSA farm. Planted 1lb of winter barley, and a small plot of perennial wheat, for demonstration and staff edification. ? Glynwoods Farm Store. Introduced 4 new grain products. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: January 2022 NOFA-NY Winter Conference. Coordinated 2 sessions on cereal rye. Moderated one session on rye markets and culinary history. Type: Other Status: Published Year Published: 2022 Citation: May 2022 Hudson Valley Bakers Convening. Developed programming for a cohort of Hudson Valley professional bakers on the northeast grainshed with presentations on; background, evolution, current research, case studies on food access programs and sourcing. Type: Other Status: Published Year Published: 2022 Citation: July 2022 Field Day, University of Vermont, Crops & Soil Sciences Alburgh, VT. Presented on market opportunities for cereal rye. Type: Journal Articles Status: Published Year Published: 2022 Citation: Bunting, J.S.; Ross, A.S.; Meints, B.M.; Hayes, P.M.; Kunze, K.; Sorrells, M.E. Effect of Genotype and Environment on Food-Related Traits of Organic Winter Naked Barleys. Foods 2022, 11, x doi.org/10.3390/foods11172642 Type: Journal Articles Status: Published Year Published: 2021 Citation: Fulcher, M.R., J.B. Winans, D., Benscher, M.E. Sorrells and G.C. Bergstrom. 2021. Triticum varieties grown as ancient grains in New York differ in susceptibility to Fusarium head blight and harbor diverse Fusarium flora. European Journal of Plant Pathology, 17. https://doi.org/10.1007/s10658-020-02183-7 Type: Journal Articles Status: Published Year Published: 2022 Citation: Massman, C., Meints, B., Hernandez, J., Kunze, K., Hayes, P. M., Sorrells, M. E., Smith, K. P., Dawson, J. C., & Gutierrez, L. (2022). Genetic characterization of agronomic traits and grain threshability for organic naked barley in the northern United States. Crop Science, 62, 690 703. https://doi.org/10.1002/csc2.20686 Type: Journal Articles Status: Published Year Published: 2022 Citation: Massman, C., Meints, B., Hernandez, J., Kunze, K., Smith, K.P., Sorrells, M.E., Hayes, P.M., and Gutierrez, L. 2022. Genomic Prediction of Threshability in Naked Barley. Crop Science. 62:690-703. Type: Other Status: Published Year Published: 2022 Citation: Caffe, M. SDSU organic variety trials. Crop Rotations on Large-Scale Organic Farm: Field Day organized by Marbleseed at Charlie Johnsons Farm. Madison, SD, July 21st. Type: Other Status: Published Year Published: 2022 Citation: Darby, H. Resonance of

Rye, March 30 and 31. Can be accessed at https://www.uvm.edu/extension/nwcrops/2021-grain-growers-conference. views 503. Type: Other Status: Published Year Published: 2022 Citation: Darby, H. Splendor of Spelt, April 8 and 9. Can be accessed at https://www.uvm.edu/extension/nwcrops/2021-grain-growers-conference. views 175. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Gautam, A., Krishnan, P., Sorrells, M., Caffe, M. Evaluation of rancidity development in naked oat genotypes during storage. Poster presentation at the National Association of Plant Breeders Annual Meeting. August 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Kunze, K.H. Malting Barley Seed Dormancy at CSSA, ASA and SSSA Trisociety annual meeting 2022, Baltimore MD November 7 Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Mallory, E. 2022. Cover crops for interseeding in small grains: Can we do better than medium red clover? Maine Agricultural Trades Show, January 10-14, Augusta, Maine. Type: Other Status: Published Year Published: 2022 Citation: Mallory, E. 2022. Organic grain research mashup: Green manures, weeds, and winterkill. New York Certified Organic (NYCO) Discussion Meeting. Cornell Cooperative Extension. February 8. Webinar. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Owen, S., A. Lambke, E. Mallory, B. Marvin, and B. Soogrim. 2022. The grain chain: Adaptations in farming, milling, and baking cereal crops in response to climate change. Kneading Conference, July 28, Skowhegan, Maine. Type: Other Status: Published Year Published: 2022 Citation: Rutkoski, J. Field day at Riggs beer company, a local farm and craft brewery in Urbana IL. The field day featured organically managed demonstration plots to educate the public about local, value-added small grains. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Sorrells, M.E. Born, Bred, and Brewed in NY: Breeding Preharvest Sprouting Resistant Barley with Good Malting Quality Crop Science Society of America Baltimore, MD Invited November 8. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Sorrells, M.E. Cornell Small Grains Breeding Program, Great Lakes Wheat Workers, Ithaca, NY March 28. Type: Book Chapters Status: Awaiting Publication Year Published: 2022 Citation: Ross, A.S., Meints, B.M., and Bunting, J.S. Barley, in Handbook of Cereal Science and Technology. International Association for Cereal Science and Technology. Accepted. Type: Journal Articles Status: Published Year Published: 2022 Citation: Sandro, P., Kucek, L.K., Sorrells, M.E. et al. Developing high-quality value-added cereals for organic systems in the US Upper Midwest: hard red winter wheat (Triticum aestivum L.) breeding. Theor Appl Genet (2022). https://doi.org/10.1007/s00122-022-04112-0 Type: Other Status: Published Year Published: 2022 Citation: Caffe, M. SDSU oat breeding. Southeast Research Farm Field Day. Beresford, SD, July 12th, 2022 Type: Other Status: Published Year Published: 2022 Citation: Sorrells, M.E. Malting Barley Varieties for New York NY Legislative Staff Field Tour October 4 Type: Other Status: Published Year Published: 2022 Citation: Sorrells, M.E. Small Grains Varieties for NY Seed Growers Field Day, Ithaca, NY June 29 Type: Other Status: Published Year Published: 2022 Citation: Sorrells, M.E. Small Grains Varieties for NYSmall Grains Management Field Day, Fayette, NY June 2 Type: Other Status: Published Year Published: 2022 Citation: April 2022 Home Bakers Meetup 2022 at Strong Rope Brewery, Red Hook, Brooklyn, New York. Type: Other Status: Published Year Published: 2022 Citation: May 2022 Hudson Valley Bakers Convening. An event co-produced by Glynwood and the Hudson Valley Farm Hub. Type: Other Status: Published Year Published: 2022 Citation: July 2022 Glynwood Farm Dinner. Featuring Regional Food Program (RFP), Grains & Staples program. Pizza Night with Justin Smillie of Il Buco Alimentari. Progress 09/01/20 to 08/31/21 Outputs Target Audience:We reached organic farmers, crop advisors, and producers through field days and webinars, and end-users such as millers, brewers, distillers, maltsters, chefs and bakers though planning for quality testing, webinars and remote quality tests. Graduate and undergraduate students were involved in the field trials and quality testing. We engaged other researchers including ag professionals, plant breeders, agronomists from academic, non-profit and industry settings through webinars and the grains week virtual conference. Through this virtual conference, we also engaged other organic organizations, consumers of local grains products and local businesses that could expand their use of local grains. Changes/Problems:COR, UW, UM, UIL:No changes UVT: There have been some delays with conducting the steam treatment research. The project team was utilizing a steam oven at a private business to carry out the work. However, with the onset of the pandemic the private business had to close its operations to outside individuals. Hence, we were unable to begin this aspect of the research. We have made the decision to purchase our own steam oven to be able to carry out the research. Glynwood, GrowNYC:In 2020-21 we were still operating in a COVID landscape and outreach to professionals was severely limited as many restaurants in New York City shuttered, have been slow to recover, and are operating under capacity, largely due to staffing shortages. Major Changes:GrowNYC Grains moved to co-locate with GrowNYC Wholesale in a warehouse in the Bronx, NY. The project's retail operation the Grainstand discontinued co-packing in February of 2021 and may wind down operations in the fall of 2021. GrowNYC capacity is being assessed as the organization has endured many challenges and changes including key staffing. At this time GrowNYC is working toward a shift of its strategic efforts to support the development of wholesale channels for regionally grown grains. Key staff changes: In April of 2021June Russell moved from GrowNYC to the Glynwood Center for Regional Food & Farming. June will continue working as a value chain coordinator in the small grains and staples sector and will continue to partner

on this project. At the time of this report, GrowNYC Food Access and Agriculture (FAA) Director, Angela Davis will become the PI for GrowNYC and Julia Raggio will be key personnel. GrowNYC is determining proposed budget changes to the project going forward and will work with June Russell to transfer some project deliverables to Glynwood. Glynwood will submit a scope, budget and letter of commitment. We anticipate submitting proposed changes to the scope and budget no later than the end of the2021\1\calendar year. Goal is December 1, 2021 What opportunities for training and professional development has the project provided?COR: Kay McNeary was admitted to our Plant Breeding Ph.D. program at Cornell. She will be helping to coordinate this project and work on developing free threshing spelt, emmer and einkorn. UW: This project is part of the training of Ms. Ing. Agr. Pablo Sandro who is a Ph.D. student in Plant Breeding and Plant Genetics graduate program at UW-Madison under the supervision of Drs. Lucia Gutierrez and Julie Dawson working on the development and selection of the winter wheat breeding population. SDSU: A MS student has been receiving training in plant breeding and cereal chemistry. The student will also receive training on organic farming practices. UM: Mallory provided two trainings for the board members of the Maine Grain Alliance on wheat growth and development and on the role grains can play in improving the environmental sustainability of agriculture. Malacarne: During the current reporting period, one graduate student has been trained in supply chain analysis, survey development, digital data collection methods, and economic impact estimation. IL:This project enabled us to train undergraduate student workers about organic research trial management. UVT: One technical staff has received training on steam treatment of grain. Technical staff attended a steam oven clinic in Providence RI. The training will help the project team complete work to determine the impact of steam treatment on seedborne diseases. Glynwood, GrowNYC:GrowNYC Teaching Garden staff planted winter barley and handled small grains for the first time. There are multiple opportunities to integrate small grains into diversified veg operations which could be tapped for seed grow outs. Development of a toolkit for beginning growers at small scale. Food safety and FSMA compliance assistance for small producers; farmers and primary processors. Need for co-packing capacity for test marketing new products. Potential for the development of a multi-stakeholder cooperative model that will continue to provide the market access and educational services that GrowNYC Grains has provided, but as a producer-led entity, or some other model. How have the results been disseminated to communities of interest?COR:The project was introduced, and results of our trials have been reported to stakeholders at our Seed Growers' field day, online and by email. UW, AGC: UW-Madison's team has been working on building the connections with the community and results have been delivered and shared on the field day and in meetings with the public or interested parties. We expect to continue working in sharing information and releasing cultivars which is the ultimate objective of product development and delivery to the community. Project results have been disseminated via AGC's newsletter, website, social media, and other listservs and newsletters of broader network and partner businesses, organizations, and institutions. SDSU: The project was introduced to organic producers at the MOSES organic field day at the Johnson's farm in Madison, SD on July 22nd, 2021. UM: The project was highlighted in all of the presentations listed under Products. The report on the economic impact of investing in grain processing infrastructure has been developed in close coordination with the Maine DACF, a key stakeholder in Maine agriculture. Retail and institutional consumer surveys are still preliminary, and results have not yet been shared. UVT: Project objectives have been shared with the local grain community primarily through a 4-part webinar series (678 views) held in March and April of 2021. The virtual events were recorded and shared through our website (https://www.uvm.edu/extension/nwcrops/2021-grain-growers-conference). In fall of 2021, an in-person event was held in Alburgh, VT. The field day allowed participants to view grain variety plots and learn about project results. There were 122 attendees at the 3-hour event. What do you plan to do during the next reporting period to accomplish the goals?COR: We will continue the evaluation of winter and spring small grains varieties under organic management. We will continue the development of free threshing spelt, emmer and einkorn. UW:We have planted the winter trials for the growing season 2021-2022. We also planted a new set of 10 lines for an expanded crossing block. We will plant the F2 seed coming from the first 15 crosses made during the 2020-2021 season. We will plant spring field trials as planned in the spring of 2022. We will plan to do an on-farm field day with involved stakeholders to discuss trials results from both on-farm and on-station. With COVID conditions permitting, we will host an in-person bake test with advanced lines near commercialization. SDSU: Our plan is to evaluate the milling and nutritional quality characteristics of the naked oat samples grown in 2021 and conduct various tests to measure the development of rancidity in stored oat samples at different times after harvest. In addition, the organic spring grains variety trials will be carried out for a second year at the Charlie Johnson's farm in 2022. UM: Conduct a second year of variety trials. (Objective 1.1) Conduct a second year of the winter survival survey and plan farmer-driven research projects to improve winter survival (Objective 2.1) Evaluate the nutritional composition of flour produced by small scale mills (Objective 3.2) Hold a research field day (Objective 4) Malacarne: During the next reporting period, the following activities will be completed under Objectives 3.1 & 3.3: Complete economic impact analysis report Put retail consumer and institutional consumer surveys into the field Analyze and disseminate results of both surveys UVT: 1) The sensory team will screen a set of cooked grains representing a range of wheat and rye varieties from multiple geographic locations. The goal will be to objectively benchmark the aroma and flavor

characteristics of cooked grains to develop detailed flavor maps that illustrate the range in aroma and flavor within the sample set. Using this information, we will work with the bakers to produce a set of wheat and rye baked sourdough bread with a wide range of aroma and flavor. We will use Profile Attribute Analysis (PAA) to evaluate both the cooked grain samples during the sensory screening phase and final sourdough bread products. 2. During the next reporting period, protocols will be developed by identifying treatment windows for wheat, oats and barley which optimize efficacy against seed-borne pathogens. In addition, the organic seed-borne disease survey will be initiated. The survey will entail collected up to 50 samples of farm-saved and commercial samples of wheat, barley, and oats. The survey will provide critical information on the state of seed health in organic small grain production. Glynwood, GrowNYC: Consumer surveys will be executed and analyzed. Some deliverables will be transferred to Glynwood with June Russell as PI. Glynwood and GrowNYC will submit a revised scope of work and budget by December 2021. Plans are underway to conduct quality evaluations of promising varieties. Discussion with project partners has begun, led by June Russell. GrowNYC and Glynwood will collaborate on strategies to continue developing the market through multiple channels, both wholesale and retail, including an exploration of a stakeholder led model that will build on the success of the GrowNYC Grainstand. Events will be determined by COVID accessibility. Outreach will continue via social media channels, conference and meeting participation and through communications with producers and end users. Impacts What was accomplished under these goals? Objective 1: Variety evaluation trials: During the 2020-2021 season, yield trials for the following small grains were carried out on certified organic farms at the indicated on-station locations. Soft Winter Wheat (11 entries): IL, ME, NY, WI, VT Hard Winter Wheat (20 entries): IL, ME, NY, WI, VT Winter Naked Barley (5 entries): IL, NY, WI Winter Spelt (9 entries): ME, NY, VT Winter Rye (9 entries): ME, NY, VT Spring Wheat (20 entries): : ME, NY, SD, WI, VT Spring Naked Barley (7 entries): ME, NY, SD, WI, VT Spring Naked Oat (18 entries): IL, ME, NY, SD, WI, VT Spring Emmer (8 entries): ME, NY, SD, VT Two on-farm trials composed of five elite lines and two commercial varieties of hard red winter wheat were grown in WI. Variety development: UW:A crossing block produced a total of 15 crosses and F3 populations will be planted in the field. A new crossing block was planted for the 2021-2022 season. : Free threshing spelt crosses were initiated and selections for free-threshing einkorn F3s were made. Free-threshing emmer selections were evaluated in a preliminary yield trial. :Nine naked oat breeding lines from SDSU oat breeding program were included in the naked oat variety trials. Quality and sensory evaluations: UW: Quality evaluation was performed on advanced hard red winter wheat lines in parallel with artisanal baking evaluations of a set of experimental lines. SDSU: Eight naked oat lines were evaluated for the development of rancidity during storage. One month after harvest, samples were evaluated for oil composition, antioxidant activity, total phenolics, free fatty acid, and hexanal and peroxidase tests were performed. Varieties exhibited different fatty acid profiles and differed significantly for antioxidant activity, total phenolics and level of free fatty acids. UVT: Project team members met in July to develop a plan for sensory evaluations on cooked grain of wheat and rye, and sourdough bread. The group will select 4-5 rye varieties and 15-20 wheat varieties from two locations for sensory this winter. Objective 2: UM: We conducted the first year of a two-year winter grain survival survey with our Vermont collaborators. Twelve fields on 6 farms in Maine and 9 fields on 5 farms in Vermont were tracked from planting until harvest with the goal of identifying the leading causes of winterkill and winter damage in Northern New England. We collected data on environmental conditions, crop management, seed quality, and crop development, and farmers provided weather observations over the winter. Snow mold, prevalent due to snow cover on unfrozen ground, was exacerbated in fields with high seeding rates and early establishment. Frost heaving was observed in fields and areas with fine-textured soils. UVT:In 2021, barley varieties were sampled to determine if closed flower morphology is associated with loose smut resistance in small grains. We prepared barley samples for digital imaging by pressing barley spikes between 3-5 layers of paper towels. We splayed the florets for imaging using theWinRHIZO image acquisition system.We scored florets as 'closed' if dark grey anthers were visible between the tips of the glumes and remained inside each floret at the head emergence stage and 'open' if the anthers protruded past the glumes.A total of 7080 florets were counted from 316 spikes, with 4198, 1647 and 1284 having 'open', 'closed' or 'undetermined' floret classification, respectively. Comparing floret classification data with disease observation data for presence of smut on barley in the field, ND Genesis and 2ND36638 and 10 other plots agreed with our hypothesis. Overall, 18 out of 32 plots scored for smut presence and floret morphology were not in agreement. These conflicting data suggest that the developmental stage at which spikes were sampled was not suitable for scoring of floret morphology or that disease pressure or infection rates were uneven or low since 10 out of the 16 varieties scored did not show evidence of smut. Objective3: UW: Held a meeting including seed industry representatives, farmers, bakers, and researchers to analyze the information available for the release of experimental lines. The decision was to add a third year of data before deciding on the release of 1 or 2 cultivars. UM: Survey instruments were created to better understand demand for organic grain products from retail consumers and institutional markets. Glynwood, GrowNYC: Worked with CUNY Urban Food Policy Institute to develop 2 consumer surveys: one to survey GrowNYC Grainstand's customer base in New York City and a second to be distributed broadly with partners in other regions. GrowNYC Grains managed a retail operation at 197 Greenmarket locations giving direct marketing opportunities to 14 producers. GrowNYC

Grains staff is working with the GrowNYC Wholesale team to integrate operations and move producers to wholesale. To date four producers have been onboarded to wholesale capable of wholesale packaging at scale. Objective4: UW: Held a field day inviting all stakeholders involved in the small grain value-added chain. Breeding efforts at UW-Madison model consultative participatory breeding efforts by incorporating the opinion of farmers, bakers, and industry in the process of development of cultivars adapted to organic systems. We participated in the Grains Week virtual conference which covered most of the project activities and were part of webinars, panels and podcasts to reach target audiences. OSU:GrainsWeek was a week-long virtual event consisting of presentations from over 80 speakers in 18 sessions to provide opportunities for stakeholders to learn about recent research by project collaborators and invited speakers ongrainbreeding, production and pest management, baking, brewing, malting, milling, marketing, value chain issues, and sensory evaluation. The program is available on the eOrganic project website athttps://www.eorganic.info/sites/eorganic.info/files/u461/Program%20Schedule_042921.pdf.GrainsWeek was presented live on YouTube so that anyone could easily access the live and recorded presentations. The full week of presentations is archived as a playlist on the Culinary Breeding Network YouTube channel at <https://www.youtube.com/playlist?list=PLgJe99mQdvfYcC4k2K8iFR-cDXOwN4ZKq> and the presentations from members of the Value Added Grains OREI projects are also available on the Value Added Grains for Local and Regional Food Systems website at <https://eorganic.info/node/34311>. There were 1449 people registered from 45 states, and post-event reports show participation from 9 countries. As of November 4, 2021, the cumulative views of the recordings on YouTube are 4312. The largest stakeholder groups were (22%), farmers (14.9%), home bakers (16.3%) and professional bakers 11.6%). The event was promoted on social media by the Culinary Breeding Network, which has over 23,000 Instagram followers, as well as in the eOrganic newsletter, which reaches over 12,000 stakeholders. The Value-added Grains project website at eOrganic (https://eorganic.info/valueaddedgrains)aggregates all project publications and presentations from project collaborators. Glynwood, GrowNYC:GrowNYC Grains staff participated in two conferences at Philly Grain and Malt Symposium and Grains Week. With our assistance, Small Valley Milling and Gianforte Farm developed new products, including packaging and labeling for retail. Grainstand Stakeholder Meeting:Glynwood and GrowNYC conducted a meeting of the 14 producer stakeholders represented by the Grainstand. The purpose of the meeting was to inform producers of changes to GrowNYC operations and to survey interest in a producer-led effort to establish an entity that would continue the services that GrowNYC Grains was providing. The response was overwhelmingly positive as producers have benefited from services and marketing exposure. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Sorrells, M.E., Cornell Small Grains Breeding and Genetics Project Value Added Grains for Local and Regional Food Systems Cornell Cooperative Extension Workshop, Virtual, Invited February 25. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Sorrells, M.E., Born, Bred, and Brewed in NY - Malting barley varieties for NY - New York State Brewers Association. Invited. March 2. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Sorrells, M.E., Accelerating Malting Barley Production in the Northeast New York State Legislators, Albany, NY. Invited. March 3. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Sorrells, M.E., Cornell Small Grains Breeding Program, Great Lakes Wheat Workers, Ithaca, NY March 16. Type: Other Status: Published Year Published: 2021 Citation: Kunze, Karl, Progress in Naked Barley Breeding. Webinar on April 14, eOrganic.org. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Sorrells, M.E., Cornell Born, Bred, and Brewed in NY Malting barley Project - Grains Week. Invited. May 3. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Sorrells, M.E., Small Grains Varieties for NY Small Grains Management Field Day (Virtual) Aurora, NY June 3. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Sorrells, M.E., Cornell Small Grains Breeding & Genetics Project Value-Added Grains for Local and Regional Food Systems. Clemson University Organic Grains conference. June 7. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Sorrells, M.E., Small Grains Varieties for NY Seed Growers Field Day, Ithaca, NY - July 1. Type: Journal Articles Status: Under Review Year Published: 2021 Citation: Sandro, S., Kissing Kucek, L., Sorrells, M.E., Dawson, J.C., and Gutierrez, L. 2021. Developing high-quality value-added cereals for organic systems in the U.S. Upper Midwest: hard red winter wheat (Triticum aestivum L.) breeding. TAG. In Revision October 31st, 2021. Type: Other Status: Published Year Published: 2021 Citation: Dawson, J.C., Telenko, D., Wepking, J., Variety selection and disease management in organic food-grade cereal grain production. OGRAIN Winter Webinar. January 22, 2021. Type: Other Status: Published Year Published: 2021 Citation: Dawson, J.C., Kissing-Kucek, L., Halloran, A. Food-Grade Grain: Behind the Seeds with Artisan Grain Collaborative. MOSES Organic Farming Podcast. April 6, 2021. Type: Other Status: Published Year Published: 2021 Citation: Dawson, J.C., Gutierrez, L. Cold weather cereal crops. Panel discussion with the Stone Barns Center and Northeast Grainshed Alliance Regenerative Farming Fellowship. Feb 25, 2021. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Dawson, J.C. Participatory wheat breeding. Presentation to the Common Grain Alliance, March 15, 2021. Type: Conference Papers and Presentations Status: Published Year

Published: 2021 Citation: Dawson, J.C., Sandro, P. Gutierrez, L. Organic Wheat Breeding. Presentation at the Great Lakes Wheat Workers conference. March 16, 2021. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Dawson, J.C., Gutierrez, L., Sandro, P., Hartman, Alyssa. Variety evaluation for artisanal bread quality. Presentation at the Grains Week virtual conference. May 6, 2021. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Dawson, J.C., Gutierrez, L., Sandro, P., Hartman, Alyssa. Wheat breeding research update. Presentation at the Grains Week virtual conference. May 6, 2021. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Dawson, J.C. Organic wheat breeding for artisanal bread making quality. Clemson University Organic Grains conference. June 7, 2021. Type: Other Status: Published Year Published: 2021 Citation: M. Leavitt, E. Mallory, and H. Darby. 2021. Agronomic management to minimize winterkill of winter grains. Grains Week, Culinary Breeding Network et al. May 3-7. Webinar. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Darby, H., J. Dawson, L. Gutierrez, and E. Mallory. 2021. Grains for cold climates, participatory breeding, and on-farm trials. Regenerative Farming Fellowship Seminar, Stone Barns Center. February 25. Webinar. Type: Other Status: Published Year Published: 2021 Citation: Mallory, E. 2021. Grains and the Environment. Maine Grain Alliance Board of Directors Meeting. January 12, Online. Type: Other Status: Published Year Published: 2020 Citation: Mallory, E. 2020. Life of a seed. Maine Grain Alliance Board of Directors Meeting. November 10, Online. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Mallory, E. 2020. Lessons learned from 11 years of organic grain variety trials. Raising Specialty Grains Webinar, 2020 Farmer-to-Farmer Conference, November 4, 2020, Online. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Grains Week was a weeklong virtual event consisting of presentations from over 80 speakers in 18 sessions. The program is available on the eOrganic project website at https://www.eorganic.info/sites/eorganic.info/files/u461/Program%20Schedule_042921.pdf Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Grains Week was presented live on YouTube. Value Added Grains NIFA OREI projects are available on the Value Added Grains for Local and Regional Food Systems website at https://eorganic.info/node/34311. Type: Websites Status: Published Year Published: 2021 Citation: Value-added Grains project website at eOrganic at https://eorganic.info/valueaddedgrains aggregates all project publications and presentations, as well as links to grain trial reports from project collaborators. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Resonance of Rye, March 30 and 31. Can be accessed at https://www.uvm.edu/extension/nwcrops/2021-grain-growers-conference. views 503. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Splendor of Spelt, April 8 and 9. Can be accessed at https://www.uvm.edu/extension/nwcrops/2021-grain-growers-conference. views 175. Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Philadelphia Grain & Malt Symposium - Naked Barley and Other Value-Added Grains. June Russell participated in a panel discussion with project partners Brigid Meints and Karl Kunze. March, 2021

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Supporting a Vibrant Organic Sector Through Economic Analysis: a Research and Extension Needs

Accession No.	1023458
Project No.	NY.W-2020-02242
Agency	NIFA NY.W\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51300-32182
Proposal No.	2020-02242
Start Date	01 SEP 2020
Term Date	31 AUG 2023
Grant Amount	$487,845
Grant Year	2020
Investigator(s)	Dimitri, C.; Pressman, AN, .
Performing Institution	New York University, 665 Broadway, Suite 801, New York, NEW YORK 10012

NON-TECHNICAL SUMMARY

Thirty years after the passage of the Organic Foods Production Act of 1990, the organic sector faces multiple challenges such as slow growth of domestic organic farm production in sectors, such as grains; viability problems for organic dairies; and difficulty sourcing needed ingredients for processed organic foods. Applied economic analysis and extension are critical to assist farmers and organic companies with key business decisions, yet there is an insufficient body of work in this area. The long-term goal of this project is to publish a national agenda for applied economic research and extension that addresses critical questions currently facing the organic sector, Towards Economic Sustainability of the Organic Sector through Applied Economic Research and Extension. The national research and extension agenda will be developed by the research team by examining existing literature and outreach programs, and analyzing new data collected from certified organic farmers, certified organic handlers and technical assistance providers. Focus groups, interviews and surveys will be used to collect the new data, which will be both qualitative and quantitative. The analysis of existing and primary data will reveal important information regarding handler needs, potential risk sharing, pricing, quality, and other factors, which can be assessed by region, product procured, or size of firm. Further, the research will identify farmer problems that are suitable for applied economic research and outreach. The analysis will provide insight into handlers and their relationships with farmer suppliers, and will provide an understanding of pressing supply chain questions that are suitable for applied economic research and outreach. The expected results and outcomes of the project will contribute to the long-term economic sustainability of organic agriculture, nationwide. We anticipate that applied economic research and extension efforts will emerge to better address the risks associated with marketing, production, management, and other risks for farmers, and that increased technical assistance and information will be available.

OBJECTIVES

The long-term goal of this project is the creation of a national agenda for applied economic research and extension that addresses critical questions facing the organic sector: Towards Economic Sustainability of the Organic Sector through Applied Economic Research and Extension (referred to as Towards Economic Sustainability). Meeting the needs of certified organic operations, both farms and handlers, has important implications for the long-term vibrancy of the sector. Many of the critical questions facing organic producers, such

as building and maintaining soil health or pest management, have important economic aspects that are not addressed in the current literature. Objective 1: Assess the state of research regarding organic farming and marketing, focusing on the organic farming and handling sector. Objective 2: Identify the needs of the organic farming sector that can be addressed through applied economic research and outreach. Objective 3: Identify the needs of the organic handling sector, particularly those related to their relationships with farmer suppliers, which can be addressed through applied economic research and outreach. Objective 4: Develop a national agenda for applied economic research and extension/outreach, Towards Economic Sustainability. Objective 5: Disseminate Towards Economic Sustainability report to ensure a broad understanding of the economic challenges facing organic agriculture, to support additional research, education, extension activities that address identified issues.?

APPROACH

The research consists of multiple, interrelated parts: (1) examining and analyzing the existing applied economics literature, research, and outreach being conducted on the organic sector, (2) collecting primary data from farmers, handlers, and technical assistance providers (3) synthesizing the findings, to develop an agenda for applied economics research and extension/outreach, and (4) disseminating Towards Economic Sustainability. Primary and secondary data will be used to identify and synthesis the current research and outreach. The secondary data analysis includes examining current outreach programs and research agendas at private and public universities, as well other technical service providers, in the United States. In addition, the research team will conduct an extensive review of the extant applied economic research literature. We will collect primary data from organic farmers, technical assistance providers, and organic handlers to assess the needs of farmers and organic businesses. By collecting primary data, we can assess farmer and organic handler concerns, which will guide our recommendations for applied economic research and outreach. All data collection instruments will be developed with feedback from the advisory committee. Primary qualitative data will be collected via focus groups of certified organic farmers and organic handlers; quantitative data will be collected by surveying technical assistance providers and handler. Analysis of the survey data will rely on descriptive statistics, which can account for product category (grains or dairy, for example) or product (apples or almonds, for example), to provide an understanding by farm product. Content analysis may be applied to the open-ended survey responses, to identify themes and concerns of handlers. Data analysis of the informant interview results will use qualitative methods, and will be organized into categories/themes that address the project\'s research questions. The analysis of the survey and interview data will reveal important information regarding handler needs, potential risk sharing, pricing, quality, and other factors, which can be assessed by region, product procured, or size of firm. This will reveal important information about handlers and their relationships with farmer suppliers, and will provide an understanding of pressing questions that are suitable for applied economic research and outreach.Furthermore, analysis of primary and secondary datawill allowthe research team identify key research and outreach needs of organic farmers.With input from our advisory committee, the primary and secondary data analysis will form the basis of our report assessing the applied economic and extension needs,Towards Economic Sustainability. Progress 09/01/20 to 08/31/24 Outputs Target Audience:The primary audience is applied economists who are interested in expanding their portfolio to include work on critical issues related to organic agriculture; technical assistance providers who work with organic producers; and farmers interested in research and technical assistance that might support the economic sustainability of their operations. In addition, NIFA\'s OREI funding program is a primary audience for this work, as they are in the position to award grant funding for research on organic food and agriculture. Changes/Problems:The main change in the study protocol was shifting from in person focus groups to the online format, due topandemic restrictions. We had planned to hold focus groups at organic farmer conferences around the country, and instead we held virtual focus groups. The new format worked out a little better, even if it took longer due to the pandemic, since we were able to have focus groups with farmers of similar products (for example, dairy, livestock, etc.) What opportunities for training and professional development has the project provided?Over the course of the project, about 6Masters students at NYU worked with the team on various aspects of the project. Theylearned about cleaning data, reviewing literature, and helped compile information on the availability of organic technical assistance through the land grant university system. A couple of the students based their capstone projects on this project, and those students learned about interpreting qualitative data and writing up findings. How have the results been disseminated to communities of interest?We gave a presentation on the research agendaat the Project Director meeting in Orlando Florida, April2024. Presentations were alo given tothe USDA Organic Working Group in August, 2024 and to the National Organic Coalition membership in October 2024. We reached a wide audience through these presentations. Once uploaded, the videos and NCAT publications will be broadly shared through the NCAT networks. 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. We completed a review of the state of literature, which is aworking paper uploaded to orgprints: Dimitri, Carolyn;Pressman, AndyandOberholtzer, Lydia(2024) Supporting a vibrant organic sector: The state of applied economic research in the U.S.https://orgprints.org/id/eprint/54223/ Objective

2. We identified the needs of the organic farming sector that can be addressed through applied economic research and outreach.This will be a series of videos that NCAT will have on their website later this fall. The topics of the four videos are (1) The farmer decision to farm organically, (2) How farmers think about and achieve profitability on their farms, (3) How are farmers getting ready for climate mitigation, and (4) How farmers balance work and life, prepare for retirement, and cope with the feelings of isolation as an organic farmer. Objective 3: We did our best to identify the needs of organic handlers, but our survey was not successful. We received many responses from bots and had approximately 100 valid responses. Objective 4: We developed a national agenda for applied economic research, which is posted on orgprints: Dimitri, Carolyn;Pressman, AndyandOberholtzer, Lydia(2024). Supporting a vibrant organic sector:Data needs and applied economic research questions.https://orgprints.org/id/eprint/54222/. The extension and outreach needs is under revision for resubmission to the peer reviewed journal, Renewable Agriculture and Food Systems. A farmer facing publication covering research needs will be posted on the NCAT website. Objective 5: Dissemination of the work. We gave a presentation on the research agenda to the USDA Organic Working Group in August, 2024, and to the National Organic Coalition membership in October 2024. The two papers were shared with the USDA Organic Working Group as well. Once they are made public, the videos and NCAT publications will be broadly shared through the NCAT networks. The team is working on a final peer reviewed article for the Journal of Agriculture, Food Systems and Community Development. Publications Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Whelan, S.J., Orlander, D., Balsam, J. and Dimitri, C., 2024. Fitting a square peg in a round hole: Applying US farm policy to organic farms. Journal of Agriculture, Food Systems, and Community Development, 13(4), pp.1-18. Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Dimitri, C., A. Pressman, L. Oberholtzer. 2024. Supporting economic sustainability of organic farms. An applied economic research agenda. Presentation to the USDA Organic Working Group. August. Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Dimitri, C., A. Pressman, L. Oberholtzer. 2024. Supporting economic sustainability of organic farms. An applied economic research agenda. Presentation to the National Organic Coalition membership. October. Type: Other Journal Articles Status: Submitted Year Published: 2024 Citation: Dimitri, C., A. Pressman, L. Oberholtzer. 2024. Supporting organic farmers through information and technical assistance. Being revised for resubmission to Renewable Agriculture and Food Systems. Progress 09/01/22 to 08/31/23 Outputs Target Audience:We were awarded a NCE in July 2023, moving the project\'s completion date to Aug 2024. During this year, our target audiences were certified organic farmers (including those who identify as BIPOC) andcertified organic handlers. Changes/Problems:We have no major changes to the project, except that the work is taking longer than anticipated. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals?During the upcoming year, we plan to: 1. Analyze survey data. 2. Draft the report and send out for peer review. 3. Begin disseminating our findingsto the research, policy and extension communities. Impacts What was accomplished under these goals? During this past year, we accomplished the following activities which support the project objectives: 1. We completed the analysis of the focus groups conducted in the previous years. 2. We completed a literature review for Objective 1. 3. We collected data from organic handlers for objective 3. 4. We completed an outline for the applied economic research and outreach report, Towards Economic Sustainability. 5. We began planning the dissemination planfor Objective 5. 6. We completed farmer interviews for podcasts, which will be published by NCAT. Publications **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:Our target audience for the past year consisted of the following kinds of certifiedorganic farmers: BIPOC, Fruit and vegetable, dairy, poultry, grain,livestock, and economically stressed. Another audience was certified naturally grown producers. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?A masters student at NYU used the focus group data for her thesis. How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals?We plan to do the following tasks: 1. Complete an article consisting of the focus group findings. 2. Complete one or two podcasts interviews with certified organic farmers. 3. Sendout technical assistance provider and handler surveys. 4. Begin drafting Towards Economic Sustainability report. **Impacts** What was accomplished under these goals? We concluded our focus groups,which shifted from in-person to remote, due to the pandemic. We made significant strides to our literature review and to the assessment of land grant and other university on-going applied economic research. We completed our advisory group review of the handler survey instrument. **Publications** Progress 09/01/20 to 08/31/21 Outputs Target Audience:This reporting period the first target audience reached included certified organic fruit and vegetable producers. The second target audience consists of BIPOC (Black, Indigenous and People of Color)certified organic producers. Changes/Problems:Due to restrictions on travel etc, as a result of the pandemic, we switched our focus groups from in person to virtual. This switch has made it challenging, since we need to actively recruit certified organic producers to participate and it is taking quite a bit of effort to locate the producers. Our advisory council and personal contacts are being used to identify our participants. What opportunities for training and professional development has the project provided? Nothing

Reported How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals?We hope to finish all of our focus groups during the upcoming year (objective 2) We plan to disseminate the survey to handlers and conduct some of the interviews (objective 3) We will continue working on the review of the current state of research (objective 1) We will begin drafting the national research agenda (objective 4) Impacts What was accomplished under these goals? Objective 1: We are in the process of conducting a thorough review of the state of literature and are currently accumulating the list of resources. Objective 2: We conducted a pilot focus group (virtual) in the spring and have a second virtual focus group scheduled for the end of August, 2021. We have met with our advisory council, who provided input into our focus group instrument. Objective 3: We are developing the survey and interview questionaire. Objectives 4 & 5:Theseparts will depend on the findings of the first three objectives. Publications

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Developing the Organic Medicinal Herb Industry

Accession No.	1023502
Project No.	OREMEDHERB2020
Agency	NIFA ORE\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51300-32188
Proposal No.	2020-02254
Start Date	01 SEP 2020
Term Date	31 AUG 2021
Grant Amount	$46,699
Grant Year	2020
Investigator(s)	Buckland, K.; Andrews, NI, .

NON-TECHNICAL SUMMARY

Fresh market and processed vegetable organic producers in the Western US are facing steep challenges to maintaining profitable production (see Introduction). Labor costs, increased food safety measures, and low prices from import competition are cutting farm profits, as much 25% in the last 5 years (personal conversation, Buckland 2019). This project will help identify new crops and barriers to adoption to direct future research for high value crop rotation option with Asian herb crops that have potential to keep farms profitable.

OBJECTIVES

The goal of this project is to provide a roadmap to industry research needs sufficient to organize and coordinate future grant proposals that will provide support to the developing organic herb industry. To foster growth in production of these crops in Oregon and Washington, this project will: Convene an industry stakeholder group. Identify promising crops for production, as well as any obstacles to their widespread adoption Identify obstacles to widespread adoption and describe research needs for a short list of promising crops.

APPROACH

Objective 1: Convene a medicinal herb production stakeholder group. Task 1: Gather medicinal herb experts for one-day production planning conference. Oregon and Washington are home to several large and many small herb farms and processing companies. This project would work to convene these farmer and processors together with other interested farmers (fresh market vegetable, specialty seed, processed vegetable, and fruit farms) and buyers of medicinal herbs in a stakeholder group. Below is a table of stakeholders contacted thus far.Table 3. Conference attendees. Name Affiliation Expertise Herbalist Experts Ben Marx1St Luke\'s Cancer Institute Acupuncture, medicinal herb research Bonnie Sweetland Oregon College of Oriental MedicineChinese medicinal herb purchasing and qualityRicho CechStrictly MedicinalsHerbal Supplier, herb qualityCasey AronGolden CabinetLargest herbal supplier in OregonHerb Farming ExpertsPeg Schafer1Chinese Medicinal HerbHerb variety sourcing, production, quality and salesRandy and Pam BureshOregon\'s Wild HarvestHerb production and salesElise HigleyOshala FarmHerb production and salesMatt DybalaHerbFarm, Pacific BotanicalsHerb production, extraction, market assessmentsPotential Adopting FarmsKristine Buckland1Oregon State UniversityVegetable and seed crop ExtensionMatt CookCook Family FarmOrganic vegetable and hemp producerNick AndrewsOregon State UniversityOrganic vegetable and small farms ExtensionRyan KochKoch

Legacy FarmsOrganic vegetable, hemp and seed producerRichard MontecuccoMontecucco Family FarmsOrganic vegetable producer1Signifies topic organizerTopic organizers (Marx, Schafer, Buckland) will solicit additional interested parties for conference preliminary inputs and in-person attendance through professional organizations (such as the Lilium Initiative https://liliuminitiative.org/about-us) and established industry connections from the project team. Target attendance for the conference is 40 individuals. Task 2: Convene this group in a one-day meeting. The diverse nature of this group, (herbalists, buyers, farmers) requires a unique event timing specific to key cooperators\' availability. We will poll cooperators for their availability to schedule conference events and offer travel support and honorariums to help offset costs of lost work time. Objective 2: Assess the potential for organic medicinal herb production in Oregon and Washington. Task 1: Identify, prioritize, and describe potential crops. While medicinal herb production is currently limited in the US and in Oregon, and there are more than 5,000 medicinal plants grown in China alone, researchers (Kraker and Giblette 2002) and farmers (HerbPharm and Pacific Botanicals) have identified a much shorter list of crops with very strong northern US production potential.Herbs currently grown in Oregon (farms with greater than 1 acre) include astragulus root, burdock root/seed, gingko leaf, bacopa and gotu kola. Other potential herbs with large market potential include ginseng root, reishi fruiting body, schisandra berry and licorice root. Herbs that are also suited to local production but with smaller yet consistent demand include: andrographis, Artemisia annua, chrysanthemum, codonopsis, eclipta, red sage, rhubarb (rheum palmatum), and Baikal skullcap.Project staff will survey additional stakeholders to adapt and refine the priority crop list and gather available production and processing information on the priority crops before convening the stakeholder meeting. The project team will consolidate information into a crop summary for each potential crop; crop summaries will be made available to stakeholders before the meeting. An example crop summary sheet is in Appendix A. We plan to organize the conference discussion in the following manner:Table 2.USDA Hardiness Zone (Zones 5-8 are suitable)Well drained soils Poorly drained soils Crops currently in production Crops currently in production AnnualAnnualShort-term perennial (1-3 years)Short-term perennial (1-3 years)Long-term perennial (3 + years)Long-term perennial(3 + years)Potential new crops Potential new cropsAnnualAnnualShort-term perennial (1-3 years)Short-term perennial(1-3 years)Long-term perennial (3 + years)Long-term perennial(3 + years)Task 2: Identify obstacles to production and processing for priority crops. Opportunities and obstacles (seed/cutting/transplant sourcing, propagation, weed/insect/disease problems, nutrient management, soil types, staking, pruning, irrigation, processing) to the production and processing of each potential crop will be described in crop summaries; the stakeholder group will further discuss these at the stakeholder meeting.Task 3: Establish research priorities for priority crops. The final task for the conference event for crops identified as high priority at the stakeholder meeting. Objective 3: Engage a broader group of stakeholders in project findings.Task 1: Develop report on potential for organic medicinal herb production in Oregon and Washington. The project team, in cooperation with the conference facilitator, will develop a comprehensive document detailing the results of exercise in Objective 1. An example of a similar conference report developed by project team members as an Organic Extension Summit Report can be found here: https://extension.oregonstate.edu/sites/default/files/documents/8161/osu-organi c-extension-summit-report-2019-final.pdf.Task 2: Make report and supporting resources available through medicinal herb production website. The meeting and priority crops summaries, as well as supporting resources for farmers and buyers will be made available at a new website (oregonmedicinalherbs.com) as well as existing Extension websites.Task 3: Assess the impacts of project. Throughout conference delivery and following the meeting, we will evaluate the success of achieving project objectives. We will assess:1. Number of stakeholders reached at conference delivery2. Number of new crops identified3. Number of research needs identified4. Conference evaluations on quality, inclusivity, and efficacy of towards achieving objectives.At the beginning of the conference, we will present the objectives and tasks for the day as described here. We will ask participants to provide a quick survey via electronic clicker to assess knowledge levels and industry needs prior to discussion exercises. Following conference delivery, we will administer an exit survey where participants will indicate their experiences and provide feedback on the process and perceived success of the conference content. Finally, following the development of the conference report, we will once again survey (via email electronic survey) the participants to assess the value and accuracy of the developed document and overall project process. **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience:The project focus was to gather experienced herb growers, herb retailers, and herb practitioners to build a collective knowledge base to identify potential crops and research questions to be addressed in future work. Our target audience for outreach materials is new or inexperienced organic growers of medicinal herb crops, experienced herb producers and industry, as well as researchers. By identifying and describing research needs of the industry, our goal was to outline an approach for future research to address the industry needs. In the long term, the project goal is to enable adoption of medicinal herb production by organic producers who are experienced in vegetable production by gaining new information in that would allow them to adopt new herb crops successfully, both diversifying their crop production and increasing farm profits. Changes/Problems:The major change that we faced was the COVID pandemic which mostly impacted the ability to meet in person. In response, we were all forced to become proficient at using tools such as Zoom for communication and therefore meeting times became very productive at great distances. Practitioner time and energy was likely reduced in

conversations due to an increased workload of patients. However, we were able to successfully hold the conference and achieve the goals while working remotely. The access to remote locations also allowed a unique opportunity to engage a diverse group who previously would not have been able to travel due to great distances; however, with the virtual conference format in place, we were able to include a much wider audience spanning the country to help achieve project outcomes. What opportunities for training and professional development has the project provided?This project did not plan to provide training and professional development. However, in switching to completely online format as required by COVID pandemic restrictions, staff and cooperators were required to become proficient at online meeting construction and preparation. Also, considerable training and information sharing between professional specialty areas of work (for example, between practitioners and producers) was integral to the conference development. By sharing information across disciplines about market needs, production limitations, and quality assessment methods, considerable training was provided participants. This impactful cross-industry approach was captured in conference outcome products for wider training opportunities through online resources described above. How have the results been disseminated to communities of interest? Conference participants (24) received a white paper with preliminary results of practitioner survey and farm visit information to inform conference discussion. The results of the conference priority setting have been consolidated in an Extension publication, currently under review. Once reviewed, the publication will be available online at <https://catalog.extension.oregonstate.edu/topic/agriculture>, free of cost. Additionally, the publication will be linked through the project webpage www.pnwherbs.org . Project results have also been presented at American Society of Horticultural Science in August 2021 (hybrid format with 15 in-person attendees, 5 online attendees, and recording available), and at three Extension events (approximately 15 attendees). Finally, a peer-reviewed publication is in progress targeting Journal of Extension to share the process of conference virtual preparation across disciplines to address the need of growers for profitable crop options. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? We successfully achieved all stated project outcomes as follows: We identified 30 crops of interest with potential to fit both growing conditions in the region as well as market opportunities. We also identified top needs of practitioners and herbalists when sourcing herb products and most frequently prescribed herbs. In preparation work leading to the conference, we conducted three farms visits with experienced herb growers, phone interviews, and surveys to assess the needs of stakeholders in all described areas. Sixty-nine practitioners and herbalists completed an industry survey and the conference included 24 participants. The planning workshop was held on March 4, 2021 and resulted in both a list of crops of potential interest as well as a plan of research and education needs to address industry needs. **Publications** - Type: Other Status: Under Review Year Published: 2022 Citation: Buckland, K.R., B. Marx, P. Schafer, A. Stone, N. Andrews. Medicinal Herb Crops for Oregon. Under review. Role: As lead author, I conducted the research, analyzed data, and wrote draft and edited manuscript. - Type: Journal Articles Status: Other Year Published: 2022 Citation: Buckland, K.R., B. Marx, P. Schafer, A. Stone, N. Andrews. An Industry Driven Approach to Sourcing and Growing Medicinal Herb Crops in Oregon. In Progress. Role: As lead author, I conducted the research, analyzed data, and wrote draft and edited manuscript. - Type: Conference Papers and Presentations Status: Other Year Published: 2021 Citation: Buckland, K., B. Marx, P. Schafer, A. Stone, N. Andrews, A. Rasmussen. Assessing Needs of Organic Medicinal Herb Industry. ASHS Conference, Aug 2021

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Developing Multi-use Naked Barley for Organic Farming Systems Ii

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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 β-glucan content. We will breed for naked barley and a modest level of β-glucan to create varietiessuitable for brewing, feed use, and that will meet FDA guidelines for soluble fiber in human diets. Development, assessment, and breeding of naked multi-use barley will be conducted in five representative regions/states - West Coast (OR, CA), Upper Midwest (MN, WI) and North East (NY) - using four classes of germplasm assessed under organic conditions: a naked barley blend targeted to K-12 students and gardeners, a large diversity panel to apply genetic data to improve barley for organic systems, a modified nested association mapping panel developed as a breeding population targeting traits important for organic systems, and a multi-regional trial to identify varieties for release. We will evaluate agronomic and multi-use quality traits and resistance to biotic and abiotic stresses. Workshops will educate stakeholders on best management practices and processing procedures. 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, California, Wisconsin, Minnesota, and New York; (3) characterize traits that were identified in the first iteration of this project as being especially critical for organic production on a large, genetically diverse panel of naked barley germplasm; (4) create a modified nested association mapping (NAM) population to breed for traits important for organic production and regionally relevant to the different areas represented in this project and to maximize the efficiency of selection via integration of phenotypic and genotypic data (5) 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; (6) educate the public on the uses and production value of naked barley using a number of dissemination techniques.

APPROACH

Oregon Naked Barley Blend The ONBB will be grown in a school garden or in pots in collaboration with the breeding program. Students will collect data on the Oregon Naked Barley Blend throughout the barley growing season. In addition, lead teachers will post descriptions and images of ongoing activities at the project website. The lead teachers in each state will provide seed, lesson plans that are aligned to the Next Generation Science Standards, and production/ processing advice to colleagues in their respective states. At each lead school, outreach, plant breeding, and graduate student personnel will be available for visits throughout the season. Regional Trial: Two trials of twenty entries each (one fall-planted and one-spring planted with five common facultative lines), composed of existing varieties, advanced lines, and two covered checks (1 general and 1 local) selected out of the diversity panel will be tested at all five states, including Oregon, California, Minnesota, Wisconsin, and New York. In each state, trials will be conducted on-farm or on-station. At each location, a three replicate Randomized Complete Block will be used. Standard yield trial protocols (e.g. plot size, seeding rate, seeding date) 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. At each location, cooperators will evaluate locally-occurring diseases using standardized rating scales. Grass and broadleaf weed estimates will be quantified in each barley variety at several timings including early-growth cycle, mid-growth cycle, and pre-harvest. At maturity, treatments will be harvested using a small plot combine and grain yield, test weight, and threshability will be evaluated. Each variety will be evaluated for food quality traits. Micromalts and malt analysis will be made and performed on all lines by the USDA-Cereal Crops Research Unit (CCRU). A subset of lines will be selected to be used for malt protocol development for naked barley. 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: In this cycle, we leverage prior value from this resource for three specific projects exploring traits that were identified as being useful for organic systems or multi-use quality, including resistance to covered and loose smut (at OSU), deoxynivalenol accumulation in the hull (UMN), and hydration index in malted kernels (OSU). The diversity panel will be assessed for resistance to covered and loose smut. Fusarium head blight (FHB) is a major disease problem across much of the barley growing region. Organic systems will need to rely on crop rotation and genetic resistance to manage this disease. Results from this study will allow us to determine the extent to which naked barley can reduce the risk of mycotoxin infection and facilitate genetic analysis of DON accumulation to inform breeding for improved disease resistance that can be deployed in organic systems. The diversity panel will be malted in teaballs in the CLP and given a hydration index measurement at 48, 72, and 96 hours into the malt process to identify lines that fully hydrate in those time periods. From there, the best lines will be tested in micro-malt batches with full malt quality analysis.Project 4: Modified NAM populationWe will be designing a modified NAM population with three common parents each crossed to 25 regional parents selected for regional traits: each of the five programs will choose five parents. The three elite common parents were selected to represent the West Coast the Midwest, and the Northeast. These will each be crossed to the 25 regional parents for a total of 75 crosses. The overall breeding targets for the entire population are based on traits identified in the first iteration of the proposal that are important for multi-use barley. The project will use the NAM population to fix essential traits using MAS, conduct GWAS for other traits of interest, and establish a large trait and marker data set to facilitate future use of GS. We will collaborate with Dr. Deven See (USDA-Pullman) to create a panel of markers for amplicon sequencing and marker asssisted selection during segregating generaitons. Trials will be conducted on-station under certified organic conditions. At the F7 stage in year two, quality traits will be centrally phenotyped at OSU. In the final year of the project at the F7 stage, tissue will be collected from a subset of 1,000 lines and will be genotyped using the latest Illumina iSelect SNP Chip. An advantage of using the Illumina iSelect SNP chip is the high marker density in the chip from which markers that are determinants of, or associated with, target traits can be identified in the population and related to prior (Illumina 9K) and (Illumina 50K) research including the Diversity Panel. Project 5: Quality CharacterizationIncrease blocks will be planted in each of the five states beginning in fall 2020 (for fall-planted varieties) and spring 2021 for spring-planted varieties. Released germplasm/varieties Streaker and Buck are two winter types that will be grown in OR and NY. Other advanced lines will be selected out of the regional trial and diversity panel. Spring increase blocks will be grown in OR, NY, MN, WI, and CA and each location will select their preferred varieties based on regional adaptation. Additionally, small commercial scale production will be initiated with interested farmers when a market has been identified. Grain harvested from these increases will belong to the farmer, who will be encouraged to sell to local maltsters, food processors, bakers, or chefs. Grain harvested from the increase blocks will be used for end-use quality analysis, product development, sensory trials, and protocol development. In the first iteration of the project, food quality and functionality was tested on the regional trial and sensory protocol was developed on pita breads. In this project, larger scale baking tests comparing advanced varieties grown in the increase blocks will be conducted. Food sensory trials will follow the

protocols developed and implemented by Julie Dawson while participating in the Cornell grains project. The Variety Showcase is an annual event which brings together over 500 attendees to taste existing, unreleased and new vegetable varieties and breeding lines focused on superior culinary quality. The goal is to build community between breeders, farmers and end users, and create a venue for the exchange of important stakeholder input into breeding projects. The grain grown from the increase blocks will be provided to chefs/bakers for these events.Pilot malts will be made at the Barley World malthouse at OSU and with cooperators. Malt quality will be assessed at the Hartwick College Center for Craft Food and Beverage. The increase blocks can produce substantially more grain that the regional trial and that grain can be used for malting.GrowNYC Greenmarket will conduct outreach to stakeholders and investigate and assess multiple markets for naked barley. 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. 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. The increase block grain will be used to prepare dishes for these events. Progress 09/01/20 to 08/31/24 Outputs 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. Producers/growers End-users Grain retailers and wholesalers Processors Millers Brewers Distillers Maltsters 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 viewers (1109 followers, 159 posts on \@nakedbarley) Consumers and farmers-market shoppers Business owners Changes/Problems:This project was originally awarded in 2020 to GrowNYC as a subcontractor of Oregon State University.In April of 2021 the PI, June Russell changed employers and moved to the Glynwood Center for RegionalFood and Farming, at which time the project was initially split between GrowNYC and Glynwood. InJanuary of 2022 the remainder of the project moved to Glynwood and a new agreement was createdbetween Oregon State University and the Glynwood Center. June Russell has consistentlymanaged the scope of work throughout the organizational transfer. Patrick Hayes, the original PIon this project, retired at the end of 2023. Brigid Meints, who was a co-PI and project manager, assumed the role of PIupon his retirement through the remainder of the no-cost extension. What opportunities for training and professional development has the project provided?Seven graduate students, two postdoctoral researchers, and a number of undergraduate students received training and professional development opportunities through this project. 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, plant pathology, disease resistance, 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 learned technical and academic skills to which they would not have otherwise been exposed. Jordyn Bunting (graduated 2021), Chris Massman (graduated 2022), John Hawkins (graduated 2022) Karl Kunze (graduated 2023), Cristiana Vallejos (graduated 2023), Gopika Gopinathan, and Siim Sepp- the graduate students who have been 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 and have been involved in leadership positions of professional scientific societies including the National Association of Plant Breeders, Craft Maltsters Guild, and the Crop Science Society of America. Brigid Meints has had the opportunity to mentor all the graduate students on the grant and serves on the thesis committee for the OSU graduate students (and some at the other institutions) and primary advisor to Cristiana Vallejos. This project has provided her with training in project management, organizing events, malting, disease inoculation, and new data analysis techniques. Additionally, attendance and presenting at the OREI PD meeting gave her exposure to other experts in the field to learn from and instigate collaborations. How have the results been disseminated to communities of interest?Outcomes and results from this research have been shared by project members at regional, national, and international conferences, including the Organic Seed Growers Conference, Marbleseed Conference, NOFA-NY, Minnesota Organic Conference, National Association of Plant Breeders Conference, Craft Malt Conference, North American Barley Researchers Workshop, Barley Mutant Conference, Women in Craft Fermentation Summit, Student Organic Seed Symposium, ASA-CSSA-SSSA Tri-Societies Conference, Michigan Brewing and Malting conference, Philadelphia Grain and Malt Symposium, and Organic Agricultural

Research Forum. Additionally, university participants have spoken at annual field days highlighting this project, with several field days organized specifically to showcase the naked barley research. Presentations have included tours of the regional trial and diversity panel to discuss production, potential varieties, disease resistance, weed management, and rotation options. Field day attendance has ranged from 20-100 participants. Over the course of the project, eOrganic has hosted several webinars on naked barley with more upcoming. We have also posted a number of bulletins and other resources to our eOrganic website. 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 over 700 people and the digital version (on eOrganic and barleyworld.org) has reached hundreds more. 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 virtual conference called \'Grains Week\' during the Covid-19 lockdown. Five of the presentations focused specifically on this project; the total views for the week were 5,113. This content is on YouTube and may garner further views in the future. Social media postings on Instagram and Facebook allow researchers to share project updates and photos with thousands of followers between \@nakedbarley, \@culinarybreedingnetwork, \@eorganicofficial, and \@glynwoodorg. The \@nakedbarley account was created specifically for this project and has 1028 followers with 153 posts. These accounts are used to distribute information about this project and have facilitated dialogues between project leaders and followers. We have been involved in the Culinary Breeding Network\'s Variety Showcase and/or Seed to Kitchen Farm to Flavor Events each year in different locations. We have been paired with various chefs and bakers to highlight breeding lines or new varieties of organic naked barley. These events draw between 100-500 attendees depending on the venue. At the 2022 Farm to Flavor event, which brought in over 200 participants, several members of the project stood at the naked barley table and talked with attendees. In 2023 we had two barley tables at the Variety Showcase hosted by the Glynwood Center for Regional Food and Farming in conjunction with our annual meeting. 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. 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. Several manuscripts have been, and are being prepared, and are in various stages of acceptance and submission to different journals, including Crop Science, APS, and the Journal of the American Society of Brewing Chemists. These include details on agronomic GxE in the fall regional trials, GWAS of several important diseases of barley, covered smut inoculation, micro-malting, weed competitive ability in naked barley, and brewing with naked malt. The results of several other studies are currently being analyzed and prepared for publication. 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. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Throughout the lifespan of this project, collaborators have grown out approximately 2000 naked barley genotypes in over 70 certified organic trials across the country, characterizing them extensively for agronomic traits, food and malt quality traits, weed competitive ability, winterhardiness, and resistance to other abiotic and biotic stressors. This comprehensive assessment of trait variation coupled with stakeholder guidance on trait importance is providing a solid foundation for new breeding work to develop varieties for organic production. The diversity panel was phenotyped for additional traits and GWAS has been resulting in the discovery of novel QTL and validation of known genes for traits including hydration index, resistance to embryo damage, covered smut, leaf rust, stripe rust, scald, and spot blotch. We initiated the development of the modified NAM population by making 75 targeted crosses, used marker-assisted selection at the F2 stage to select for naked lines, have advanced population using speed breeding, and 1400 mid-generation genotypes were grown in the field in the spring of 2024 for field evaluation and genomic selection. Thousands of growers, processors, and consumers have been provided with trial results and information about naked organic barley at conferences, field days, webinars, website postings, social media, and through personal communication. Goal 1: The value of naked barley as a new potential crop was described to stakeholders through a variety of mechanisms. A brewing study was conducted at OSU on three naked barley lines and one covered check using grain malted at OSU with two brewing technologies. These data were provided to maltsters and brewers at the Craft Malt Conference, an eOrganic webinar, and at the Women\'s Craft Fermentation Summit. In MN, a six-acre grain increase of MS10S4111-01, an advanced breeding line, was conducted for large-scale end-use testing and distribution to interested end-users. Using this grain, Kevin Smith worked with a malthouse and homebrewing group to demonstrate the potential of naked barley for malting and brewing, which was made into a video and put on YouTube. In WI, blocks of two naked barleys were grown on-farm for larger scale testing. 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. Glynwood has been working with Northeast farmers to grow and market white, purple, and black barley lines. Goal 2: The regional variety trials were grown in all years of the grant and comprised two trials of advanced experimental breeding lines and released varieties planted in the fall and spring. For the fall trial, 18 advanced naked barley lines were tested at 5 sites in five states: Oregon, Minnesota, Wisconsin, California, and New York. For the spring trial, 18 naked barley entries were tested at 5 sites in the same five states. Genotypes were assessed for grain yield, test weight, plant height, heading date, disease resistance, winter survivability and weed competitive ability. The FRT was evaluated for scald in Ithaca and Corvallis. The SRT was also evaluated for FHB in St. Paul and Ithaca, spot blotch, net blotch, and bacterial leaf streak inoculated disease trials in St. Paul and leaf rust and stripe rust in Corvallis. Analyses of agronomic data are in progress. Samples from trials were sent to the USDA-ARS Cereal Crops Research Unit for micro-malting and analysis and will be assessed for food quality traits at OSU. The fall-planted trials had differential winter survival in WI, MN, and CA in the different years of the project that allowed us to gather data on winterhardiness. The trials were terminated after taking notes on differential winter survival. 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. Goal 3: Threshability, or ease of hull loss, was identified as a key trait for naked grains in the first cycle of the grant. Using information from the diversity panel, research was done on the genetic basis and plausibility of genomic prediction for threshability. The data set includes nine environments where threshability was scored for 350 distinct barley genotypes. GWAS was performed to identify two QTL with a significant association to threshability. Using genomic prediction models, predictive ability for threshability was 0.84 using genomic best linear unbiased prediction. A manuscript was submitted and accepted with minor revisions in the Crop Science journal. In MN, grain samples from the 2021 FHB trial of the OREI Spring Diversity Panel were processed to separate kernels from hulls and the subsamples were submitted for DON analysis. The results indicate considerable variation for DON concentration in the hulls and kernels among the lines in the panel.Data are being prepared for publication. In Corvallis, inoculation studies for covered smut (incited by Ustilago hordei) were completed. Brigid Meints presented on this project at the North American Barley Researchers Workshop and ASA-CSSA-SSSA International Meeting. Heads from one year and one replication of the spring diversity panel were threshed under four different protocols and a control. Seed was then evaluated and germinated to look at resistance to embryo damage. Preliminary data are still being analyzed but show that there is a genetic component to embryo damage. Goal 4: The modified NAM population was developed, with crosses initially made in the spring/summer of 2020 at each location. Working with the USDA-ARS lab at Fargo, ND, we developed a KASP marker set that was used for marker-assisted selection for the nud allele during the F2 generation. F3 seed from OR, CA, and NY was sent to Madison, WI and St. Paul, MN for generation advance of the entire population. Heads were grown in the field under certified organic conditions in the spring of 2023 to select out genotypes that required vernalization. F4 heads were selected from all families that flowered and seed was planted in the greenhouse to increase to the F5 generation using single seed descent. In the spring of 2024, 1371 mid-generation genotypes from 65 families were sent to Corvallis, OR for a seed increase. 430 genotypes were selected and harvested to be used for genomic selection. Goal 5: New lesson plans that meet curriculum standards for multiple grade levels were created that will have options for in-person or virtual learning. Pat Hayes and Brigid Meints presented to a group of teachers interested in agriculture in the classroom who were interested in in-person classroom visits in the upcoming school year. Pat Hayes and Cristiana Vallejos visited middle and high school classrooms to engage with students about genetics and plant breeding related to naked barley. The Oregon Naked Barley Blend has been distributed to teachers and dozens of pounds of the blend have been distributed to interested home gardeners around the country for planting and selection. Goal 6: Details of the project have been disseminated through email, personal correspondence and communication, in-person field days, social media, conferences, and websites. The eOrganic website is updated to reflect progress of the project and contains bulletins, publications, webinars, and social media accounts. UW-Madison, Cornell, UC Davis, OSU, and UMN all hosted in-person field days with hundreds of participants gathering and interacting with researchers and students.At field day events, chefs and bakers prepared barley dishes for participants to taste. Publications Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Kunze, K.H., Meints, B., Massman, C., Guti&#65533;rrez, L., Hayes, P.M., Smith, K.P. and Sorrells, M.E., 2024. Genotype&#65533; environment interactions of organic winter naked barley for agronomic, disease, and grain quality traits. Crop Science, 64(2), pp.678-696. Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Mart&#65533;nez-Subir&#65533;, M., Meints, B., Tomasino, E. and Hayes, P., 2024. Effects of roasting and steeping on nutrients and physiochemical compounds in organically grown naked barley teas. Food Chemistry: X, 22, p.101385. Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Kunze, K.H., Meints, B., Massman, C., Guti&#65533;rrez, L., Hayes, P.M., Smith, K.P., Bergstrom, G.C. and Sorrells, M.E., 2024. Genome?wide association of an organic naked

barley diversity panel identified quantitative trait loci for disease resistance. The Plant Genome, p.e20530. Progress 09/01/22 to 08/31/23 Outputs 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. · Producers/growers · End-users o Processors o Grain retailers and wholesalers o Millers o Brewers o Distillers o Maltsters Organic poultry egg and meat producers Animal feed suppliers and feed mills o Chefs o Bakers · Students o K-12 students o Undergrad and graduate students o Urban agriculture students · Academic and industry researchers · Organic organizations · General Public o Instagram/Facebook viewers (996 followers, 150 posts on \@nakedbarley, posts also shared by \@culinarybreedingnetwork which has 27.5K followers) o Consumers and farmers-market shoppers o Business owners Changes/Problems:In 2021 the subcontract originally awarded to GrowNYC was revised and split evenly with Glynwood due to June Russell\'s (Key collaborator) move from GrowNYC to Glynwood. In January of 2023 GrowNYC abdicated their role and scope of work on the project and referred the remaining scope of work and project funds to Glynwood. This was agreed to by the Project PI. What opportunities for training and professional development has the project provided?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, plant pathology, disease resistance, 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 learned technical and academic skills to which they would not have otherwise been exposed. Karl Kunze (graduated 2023), Cristiana Vallejos (graduated 2023), Gopika Gopinathan, and Siim Sepp- the breeding graduate students who have been 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 and have been involved in leadership positions of professional scientific societies including the National Association of Plant Breeders, Craft Maltsters Guild, and the Crop Science Society of America. Brigid Meints has had the opportunity to mentor all the graduate students on the grant and serves on the thesis committee for the OSU graduate students (and some at the other institutions) and primary advisor to Cristiana Vallejos. This project has provided her with training in project management, organizing events, malting, disease inoculation, and new data analysis techniques. Additionally, attendance and presenting at the OREI PD meeting gave her exposure to other experts in the field to learn from and instigate collaborations. 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, UC Davis, OSU, and UMN all hosted in-person field days with hundreds of participants gathering and interacting with researchers and students.At field day events, chefs and bakers prepared barley dishes for participants to taste. Several manuscripts have been, and are being prepared, and are in various stages of acceptance and submission to different journals, including Crop Science, APS, and the Journal of the American Society of Brewing Chemists. These include details on agronomic GxE in the fall regional trials, GWAS of several important diseases of barley, covered smut inoculation, micro-malting, weed competitive ability in naked barley, and brewing with naked malt. The results of several other studies are currently being analyzed and prepared for publication. The Culinary Breeding Network organized the 2022 Sagra del Radicchio, which brought in over \~375 attendees. Jordyn Bunting prepared a barley risotto dish to highlight whole grain barley and several members of the project stood at the naked barley table and talked with participants throughout the evening. Glynwood hosted a Hudson Valley Value-Added Grains School and a Home Bakers meet-up that both featured barley and included barley packages and zines for guest giveaways. Social media postings in Instagram and Facebook allow researchers to share project updates and photos with thousands of followers between \@nakedbarley, \@culinarybreedingnetwork, \@eorganicofficial, and \@glynwoodorg. Brigid Meints, Karl Kunze, and Cristiana Vallejos presented in oral and poster presentations at the ASA-CSSA-SSSA in the Plant Breeding section on weed competitive ability, malting quality of naked barley, and covered smut. Brigid Meints, Karl Kunze, Cristiana Vallejos, and Kevin Smith presented at the 2022 North American Barley Researchers Workshop on weed competitive ability, resistance to embryo damage, malting naked barley, FHB in naked barley, and covered smut. 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. 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: Food quality from spring regional trial Weed competitive ability GWAS results on diseases Brewing trials Malting research Smut and FHB inoculation studies · Education Work with teachers at the local schools to implement previously developed lesson plans Work with teachers at the local schools to find ways to involve students in the naked barley project. · Outreach Continue to educate our target audience through workshops and conferences- either in-person or virtual (Variety Showcase, Winter Vegetable Sagra, MarbleSeed, Organic Seed Growers Conference, Craft Malt Conference, Barley Improvement Conference). Gather and provide information on research and opportunities for growers, processors, bakers, and brewers to gain access to naked barley. Conduct expanded outreach to professionals in the craft beverage and culinary sectors. Host field days and other outreach events to increase community involvement and awareness. Research Advance the NAM population to further assess naked barley germplasm and gather more data on traits determined to be important for its production. Conduct loose smut inoculation trials on the diversity panel in the greenhouse at OSU. Conduct brewing trials with the OSU Fermentation Science program. Consider variety release of MS10S4111-01, Purple Prince, and other advanced germplasm. Impacts What was accomplished under these goals? In the third year of the grant, participants grew out the third year of trials for this project, including regional trials and breeding lines from the NAM. This involved growing \~1500 naked barley lines (\~400 fixed lines including released varieties and advanced breeding lines, and \~1100 early generation segregating lines in 70 families for the NAM) in certified organic trials. Advanced lines were characterized for agronomic traits, food and malt quality traits, weed competitive ability, and resistance to abiotic and biotic stressors. Early generation material was screened for growth habit. 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, 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. Kevin Smith worked with a malthouse and homebrewing group to demonstrate the potential of naked barley for malting and brewing, which was made into a video and put on YouTube. Glynwood has been working with Northeast farmers to grow and market white, purple, and black barley lines. Andrew Ross\'s lab began working on a flaking study with four varieties of naked barley in order to educate the public on novel uses of naked barley. This study will continue and the protocol will be published when finished. Goal 2: For the 2022-23 regional variety testing program we grew advanced experimental breeding lines and released varieties in the fall and spring. For the fall trial, 18 advanced naked barley lines were tested at 5 sites in five states: Oregon, Minnesota, Wisconsin, California, and New York. For the spring trial, 18 naked barley entries were tested at 5 sites in the same five states. Genotypes were assessed for grain yield, test weight, plant height, heading date, disease resistance, winter survivability and weed competitive ability. The FRT was evaluated for scald in Ithaca and Corvallis. The SRT was also evaluated for FHB in St. Paul and Ithaca, spot blotch, net blotch, and bacterial leaf streak inoculated disease trials in St. Paul and leaf rust and stripe rust in Corvallis. Analyses of agronomic data are in progress. Samples from trials were sent to the USDA-ARS Cereal Crops Research Unit for micro-malting and analysis and will be assessed for food quality traits at OSU. The fall-planted trials had low winter survival in WI, MN, and CA and trials were terminated after taking notes on differential winter survival. 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. Goal 3: In Corvallis, inoculation studies for covered smut (incited by Ustilago hordei) were completed. Data is being analyzed and prepared for publication. Brigid Meints has presented on this project at the North American Barley Researchers Workshop and ASA-CSSA-SSSA International Meeting. Heads from one year and one replication of the spring diversity panel were threshed under four different protocols and a control. Seed was then evaluated and germinated to look at resistance to embryo damage. Preliminary data are still being analyzed but show that there is a genetic component to embryo damage. Based on hydration index measurements, micro-malting using four protocols was conducted on seven naked genotypes and one covered check. Cristiana Vallejos (MS student) presented on these data at the North American Barley Researchers Workshop. Goal 4: Development of the modified NAM population continued. F3 seed from OR, CA, and NY was sent to Madison, WI and St. Paul, MN for generation advance of the entire population. Heads were grown in the field under certified organic conditions in the spring of 2023 to select out genotypes that required vernalization. F4 heads were selected from all families that flowered and seed was planted in the greenhouse to increase to the F5 generation. Goal 5: Brigid Meints presented to a group of teachers interested in agriculture in the classroom who were interested in in-person classroom visits in the upcoming school year. Pat Hayes and Cristiana Vallejos visited middle and high school classrooms to engage with students about genetics and plant breeding related to naked barley. The Oregon Naked Barley Blend has been distributed to teachers and dozens of pounds of the blend have been distributed to interested home gardeners around the country for planting and selection. Goal 6: Details of the project have been disseminated through email, personal correspondence and communication, in-person field days, social media, conferences, and websites. The eOrganic website is updated to reflect progress of the project and contains bulletins, publications, webinars, and social media accounts. Brigid Meints, Karl Kunze, and Cristiana Vallejos presented oral and poster presentations at the Tri-Societies conference. Brigid Meints, Karl Kunze, Cristiana

Vallejos, and Kevin Smith presented at the North American Barley Researchers Workshop. Gopika Gopinathan presented a poster at the National Association of Plant Breeders conference. Julie Dawson presented virtually to the Bread Bakers Guild of America and OGRAIN about the project. Brigid Meints presented at the OREI PD Meeting in Washington DC. Participants at OSU, UMN, UW-Madison, Cornell, and UC Davis all hosted field days and interacted with hundreds of growers and other stakeholders. Jordyn Bunting, Brigid Meints, and Cristiana Vallejos participated in the Sagra del Radicchio organized by Lane Selman and served a barley risotto while educating the general public about naked barley. Publications Type: Journal Articles Status: Under Review Year Published: 2023 Citation: Kunze, K., Meints, B., Massman, C., Gutierrez, L., Hayes, P.M., Smith, K., and Sorrells, M. Genotype x Environment Interactions of Organic Winter Naked Barley for Agronomic, Disease and Grain Quality Traits. In press. Type: Book Chapters Status: Published Year Published: 2023 Citation: Ross, A.S., Meints, B.M., and Bunting, J. 2023. Barley, In ICC Handbook of 21st Century Cereal Science and Technology. Eds., Shewry, P.R., Koksel, H. and Taylor, J.R. Elsevier, pp. 153-160. Type: Theses/Dissertations Status: Published Year Published: 2023 Citation: Kunze, K., 2023. Genomic And Phenotypic Characterization of Malting Barley and Naked Multi-use Barley as Winter Crops for New York State (Doctoral dissertation, Cornell). Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Gopinathan, G., Sandro Garcia, P., Meints, B., Gutierrez, L. 2023. Speed breeding with early harvest in naked barley to accelerate genetic gain. National Association of Plant Breeders Conference, Greenville, SC. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Meints, B., Vallejos, C., Hayes, P. M., 2022. Screening a Diverse Set of Naked Barley for Resistance to Covered Smut. ASA, CSSA, SSSA International Annual Meeting. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Kunze, K., Meints, B., Massman, C., Gutierrez, L., Hayes, P.M., Sorrells, M. E., 2022. Genotype By Environment Interaction of Organic Winter Naked Barley. ASA, CSSA, SSSA International Annual Meeting. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Vallejos, C., Fisk, S., Hayes, P., Meints, B. 2022. Manipulating Steep and Germination Protocols to Improve Malting Quality Profiles of Naked Barley. ASA, CSSA, SSSA International Annual Meeting. **Progress** 09/01/21 to 08/31/22 **Outputs** 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. 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 (878 followers, 136 posts on \@nakedbarley) Consumers and farmers-market shoppers Business owners Changes/Problems:Problem: Visits and experiments with K-12 schools remained challenging due to the COVID-19 pandemic. Solution: Planned activities were canceled and will be restarted in the fall of 2022. 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: Shortage of grain for GrowNYC Grains to work with and market. 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: Heavy rains after planting and crow damage in Davis, CA resulted in loss of the SRT Solution: The trial was replanted at Tulelake, CA. 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, plant pathology, disease resistance, 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 learned technical and academic skills to which they would not have otherwise been exposed. Chris Massman (graduated 2022), Karl Kunze, John Hawkins (graduated 2022), and Cristiana Vallejos- the breeding graduate students who have been 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 and have been involved in leadership positions of professional scientific societies including the Organic Seed Alliance, National Association of Plant Breeders, and

the Crop Science Society of America.At the 2022 annual meeting for this project, graduate students (current and recent) presented their research projects to co-PIs and stakeholders and helped generate future research project ideas. The food quality analyses being run at OSU provided opportunities to train a graduate student, Jordyn Bunting (graduated Dec 2021) and undergraduate student 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 has had the opportunity to mentor all of the graduate students on the grant and serves on the thesis committee for the OSU graduate students and primary advisor to Cristiana Vallejos. Brigid also had the opportunity to moderate the session on 'Breeding for Organic Management Systems Oral: What Are the Priority Traits and Breeding Methods?' at the 2021 ASA-CSSA-SSSA conference. 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, UC Davis, OSU, and UMN hosted in-person field days. A report of the field day at Corvallis, OR was posted to the eOrganic research updates page. Several manuscripts were prepared and are in various stages of acceptance in different journals, including Crop Science, Foods, and the Journal of Distilling Science. These include details on agronomic GxE in the spring regional trials, GWAS and genomic prediction of threshability, food quality and functionality traits in the fall regional trials, and an experiment on grain-on whiskey distillation with naked barley. The results of several other studies are currently being analyzed and prepared for publication. The Culinary Breeding Network, Artisan Grains Collaborative, and Seed to Kitchen Collaborative organized the 2022 Farm to Flavor event, which brought in over 200 attendees. Jordyn Bunting prepared a barley panzanella dish to highlight flour and whole grain barley and several members of the project stood at the naked barley table and talked with participants throughout the evening. Glynwood hosted a Hudson Valley Bakers Convening and a Farm dinner that both featured barley, and included barley packages for guest giveaways. Additionally, in collaboration with GrowNYC Grains, they hosted a home baker's meetup that featured barley products, including a barley milk. GrowNYC Grains x Glynwood also put out an updated barley flyer on 'Demystifying Barley' for consumers. Social media postings in Instagram and Facebook allow researchers to share project updates and photos with thousands of followers between \@nakedbarley, \@culinarybreedingnetwork, \@eorganicofficial, \@glynwoodorg, and \@grownycgrains. Brigid Meints, Karl Kunze, and Chris Massman presented in oral and poster presentations at the ASA-CSSA-SSSA in the Organic Plant Breeding section on threshability, weed competitive ability, resistance to embryo damage, and covered smut. Brigid Meints, Karl Kunze, Cristiana Vallejos, and Chris Massman presented at the virtual 2022 Organic Seed Growers Conference on threshability, weed competitive ability, resistance to embryo damage, and covered smut. Karl Kunze presented on organic naked barley at the 2022 Michigan Brewing and Malting conference. Jordyn Bunting of OSU presented an eOrganic webinar entitled Food Functionality of Naked Barley. Available at https://www.youtube.com/watch?v=xnDLmCLRHqU&t=1s 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. 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: Agronomics GxE from fall regional trial Food quality from spring regional trial Weed competitive ability GWAS results on diseases Brewing trials Malting research, Smut and FHB inoculation studies Poultry layer and broiler trial Education Work with teachers at the local schools to implement previously developed lesson plans Develop new lesson plans for a variety of curriculum standards and grades Work with teachers at the local schools to find ways to involve students in the naked barley project. 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, 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 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 2023. Attend and prepare posters for conferences including the upcoming ASA-CSSA-SSSA meetings to share and discuss results with other

researchers. Research Initiate new crosses and continue to select and advance cross progeny for variety development. Conduct field trials including the spring/fall regional trials as well as the NAM population to further assess naked barley germplasm and gather more data on traits determined to be important for its production. Conduct sensory trials using grain harvested in the 2021 and 2022 harvest season to assess genotypes for their use in baking as well as further outreach and get feedback from bakers. Conduct loose smut inoculation trials on the diversity panel in the greenhouse at OSU. Consider variety release of MS10S4111-01. **Impacts** What was accomplished under these goals? In the second year of the grant, participants grew out the second year of trials for this project, including regional trials and the diversity panel. 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. All the crosses for the NAM were completed and advanced in the greenhouse. Marker assisted selection for the nud allele was conducted at the F2 generation. 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. A brewing study was conducted at OSU on three naked barley lines and one covered check using grain malted at OSU with two brewing technologies. These data will be provided to maltsters and brewers. In WI, blocks of two naked barleys were grown on-farm for larger scale testing. GrowNYC and Glynwood have been working with Northeast farmers to grow and market purple and black barley lines. Goal 2: For the 2021-22 regional variety testing program we grew advanced experimental breeding lines and released varieties in the fall and spring. For the fall trial, 18 advanced naked barley lines were tested at 5 sites in five states: Oregon, Minnesota, Wisconsin, California, and New York. For the spring trial, 18 naked barley entries were tested at 5 sites in the same five states. Genotypes were assessed for grain yield, test weight, plant height, heading date, disease resistance, winter survivability and weed competitive ability. The FRT was evaluated for scald in Ithaca and Corvallis The SRT was also evaluated for FHB in St.Paul and Ithaca;, spot blotch, net blotch, and bacterial leaf streak inoculated disease trials in St. Paul and leaf rust and stripe rust in Corvallis. Analyses of agronomic data are in progress. The fall-planted trials had low winter survival in WI and MN and trials were fully or partially terminated after taking notes on differential winter survival. 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 trial at Davis, CA was unsuccessful due to high rainfall after planting and seedling removal by crows and was replanted at Tulelake, CA. After that, all spring trials survived at all locations and data are being collected and analyzed. Goal 3: Threshability, or ease of hull loss, was identified as a key trait for naked grains in the first cycle of the grant. Using information from the diversity panel, research was done on the genetic basis and plausibility of genomic prediction for threshability. The data set includes nine environments where threshability was scored for 350 distinct barley genotypes. GWAS was performed to identify two QTL with a significant association to threshability. Using genomic prediction models, predictive ability for threshability was 0.84 using genomic best linear unbiased prediction. A manuscript was submitted and accepted with minor revisions in the Crop Science journal. In MN, grain samples from the 2021 FHB trial of the OREI Spring Diversity Panel was processed to separate kernels from hulls and the subsamples were submitted for DON analysis this past winter from the St. Paul and for about half of the Crookston location.The remaining samples will be submitted this fall. Initial analyses indicate considerable variation for DON concentration in the hulls and kernels among the lines in the panel.Data is currently being analyzed. In Corvallis, inoculation studies for covered smut (incited by Ustilago hordei) were conducted. Based on hydration index measurements, micro-malting using four protocols was conducted on seven naked genotypes and one covered check. For both studies, data are being analyzed and will be presented and published. Goal 4: Development of the modified NAM population continued at all locations. F2 plants were grown out. Working with the USDA-ARS lab at Fargo, ND, we developed a KASP marker set that was used for marker-assisted selection for the nud allele. F3 and future generations will be grown out using single seed descent. Goal 5: In-person classroom visits were still suspended because of Covid-19. However, researchers are continuing to work with teachers to find ways to provide distance learning and educational resources safely. Additionally, new lesson plans that meet curriculum standards for multiple grade levels were created that will have options for in-person or virtual learning. Pat Hayes and Brigid Meints presented to a group of teachers interested in agriculture in the classroom who were interested in in-person classroom visits in the upcoming school year. The Oregon Naked Barley Blend has been distributed to teachers and continues to be distributed to interested home gardeners for planting and selection. Goal 6: Details of the project have been disseminated through email, personal correspondence and communication, in-person field days, social media, conferences, and websites. The eOrganic website is updated to reflect progress of the project and contains bulletins, publications, webinars, and social media accounts. At the 2022 Farm to Flavor event, which brought in over 200 participants, several members of the project stood at the naked barley table and talked with attendees. Jordyn Bunting shared his research on food quality and functionality in an eOrganic webinar. Brigid Meints, Karl Kunze, and Chris Massman presented oral and poster presentations at the Tri-Societies conference. Brigid Meints, Karl Kunze, Cristiana Vallejos, and Chris Massman presented at the virtual Organic Seed Growers

Conference. Brigid Meints presented at the American Craft Spirits Association conference, John Hawkins presented at the National Fusarium Head Blight Virtual Forum. Participants at OSU, UMN, UW-Madison, Cornell and UC Davis were able to hold in-person field days. **Publications** - Type: Journal Articles Status: Published Year Published: 2022 Citation: Massman, C., Meints, B., Hernandez, J., Kunze, K., Hayes, P.M., Sorrells, M.E., Smith, K.P., Dawson, J.C. and Gutierrez, L., 2022. Genetic characterization of agronomic traits and grain threshability for organic naked barley in the northern United States. Crop Science, 62(2), pp.690-703. - Type: Journal Articles Status: Accepted Year Published: 2022 Citation: Massman, C., Meints, B., Hernandez, J., Kunze, K., Smith, K.P., Sorrells, M.E., Hayes, P.M., and Gutierrez, L. Genomic Prediction of Threshability in Naked Barley. Crop Science. Accepted with minor revisions. - Type: Journal Articles Status: Awaiting Publication Year Published: 2022 Citation: Bunting, J.S.; Ross, A.S.; Meints, B.M.; Hayes, P.M.; Kunze, K.; Sorrells, M.E. Effect of Genotype and Environment on Food-Related Traits of Organic Winter Naked Barleys. Foods 2022, 11, x. https://doi.org/10.3390/xxxxx - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Meints, B., Kunze, K., Massman, C., and Vallejos, C. 2022. Breeding Barley for Organic Systems. In Proceedings for the Organic Seed Growers Conference. - Type: Theses/Dissertations Status: Published Year Published: 2022 Citation: Massman, C., 2023. Organic Multiuse Naked Barley Characterization and Genomic Studies (Doctoral dissertation, The University of Wisconsin-Madison). - Type: Theses/Dissertations Status: Published Year Published: 2021 Citation: Bunting, J.S., 2021. Effect of Genotype and Environment on Organic Winter and Spring Naked Barley Composition and Food Functionality.

PROGRESS

2020/09 TO 2021/08 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 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. Problem: At UW-Madison, incorrect field dimensions in the spring regional trial prevented planting of the experiment as originally planned. Solution:

Planting layout was adjusted in-field and phenotypes were assessed throughout the season to ensure that changes were properly recorded. Problem: Spatial variability in the field, combined with a spring drought, let to phenotypic variability within genotypes of the spring regional trial. Solution: Data was recorded for plots affected that can be used as covariates when analyzing the trial. Problem: A high variability in maturity date between genotypes in the fall regional trial led to some lines being ready for harvest weeks sooner than other lines. Solution: To avoid yield losses and penalization of early lines, the experiment was harvested in two stages. Harvest date was recorded for each line and can be used to correct for differences between harvest dates. Personnel Changes at GrowNYC GrowNYC Grains moved to co-locate with GrowNYC Wholesale in a warehouse in the Bronx, NY. The project\'s retail operation the Grainstand discontinued co-packing in February of 2021 and will wind down operations in the fall of 2021. At this time GrowNYC is working toward a full shift of its strategic efforts to support the development of wholesale channels for the regionally grown grains. Key staff changes: June Russell moved from GrowNYC in April of 2021 and is working with the Glynwood Center for Regional Food & Farming. June will continue working as a value chain coordinator in the small grains and staples sector and will continue to partner on the project. At the time of this report, GrowNYC FAA Assistant Director Cheryl Huber is determining proposed budget changes to the project going forward. 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, plant pathology, disease resistance, 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, John Hawkins, 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. Karl Kunze was the local student liaison for the Graduate Student Working Group of the National Association of Plant Breeders and will be student representative for the Crop Science Society of America board starting in 2022. 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 students. 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, UC Davis, 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/oW0FjspbsMo. 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. Incollaboration 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. Incollaboration with Portland-based pastamaker Emily Park, offeredbarley pasta kitsfor sale during Grains Week. Incollaboration 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 kid\'s meals at each location. 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 first iteration of 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 poultry layer and broiler trial publications.Report results to appropriate audiences as available. Submit a publication characterizing genotype by environment interactions effecting naked barley germplasm and mega-environment delineation for breeding efforts. Submit publications investigating the genetic basis of threshability and weed competitive ability including a GWAS analysis and Genomic selection Education Work with teachers at the local schools to reach out to students safely, whether that be in a distance in-person or virtual format. Provide seed and teaching resources for students to perform their own experiments at home. Develop lesson plans for a variety of curriculum standards and grades that can be taught in-person or remotely. Work with teachers at the local schools to find safe ways to involve students in the naked barley project. 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 2022. Find effective and safe ways to host field days, seminars and presentations to reach organic farming communities Attend and prepare posters for conferences including the upcoming ASA-CSSA-SSSA meetings to share and discuss results with other researchers. Research 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 2021. Use the data from 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 2021 regional experiments to do more in depth testing and analysis including baking and quality trials. Conduct field trials including the spring/fall regional trials as well as the NAM population to further assess naked barley germplasm and gather more data on traits determined to be important for its production. Conduct sensory trials using grain harvested in the 2021 harvest season to assess genotypes for their use in baking as well as further outreach and get feedback from bakers. Conduct covered and loose smut inoculation trials on the diversity panel in the greenhouse at OSU. Assist in continuing NAM population development and genotyping. Complete data collection from two years (2 locations per year) evaluating the Diversity Panel for FHB severity and DON concentration in kernels and hulls. Initiate

GWAS studies on DON accumulation in kernels and hulls. UMN will work with Vertical Malt to produce 10,000 lb of malt of MS10S4111-01 for evaluation by Minnesota brewers. Consider variety release of MS10S4111-01.

IMPACT

2020/09 TO 2021/08 What was accomplished under these goals? In the first year of the grant, participants grew out the first year of trials for this project, including regional trials and the diversity panel. 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 from the first iteration of this project, lines were selected as parents for the Modified NAM population, crosses were made, and F1s were grown out. 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, was 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: For the 2020-21 regional variety testing program we grew advanced experimental breeding lines and released varieties in the fall and spring. For the fall trial, 18 advanced naked barley lines were tested at 5 sites in five states: Oregon, Minnesota, Wisconsin, California, and New York. For the spring trial, 18 naked barley entries were tested at 5 sites in the same five states. Genotypes were assessed for grain yield, test weight, plant height, heading date, disease resistance, winter survivability and weed competitive ability. The FRT was evaluated for scald in Ithaca and Corvallis. The SRT was also evaluated for FHB, spot blotch, net blotch, and bacterial leaf streak inoculated disease trials in St. Paul and leaf rust and stripe rust in Corvallis. 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 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.The FRT in Davis, CA was evaluated under extreme drought conditions and low inputs with no irrigation. Identification and development of varieties that can perform under these conditions are becoming increasingly important for organic grain farmers in West that rely on dry farming systems. Goal 3: 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. In MN, grain samples from the 2020 FHB trial of the OREI Diversity Panel was processed to separate kernels from hulls and the subsamples were submitted for DON analysis this past winter from the St. Paul location. Initial analyses indicate considerable variation for DON concentration in the hulls and kernels among the lines in the panel. UMN grew out the panel in the spring of 2021 in three disease nurseries (FHB, spot blotch, net blotch, and bacterial leaf streak). Data is currently be compiled. In Corvallis, the 254 lines from the spring diversity panel were grown in single rows in the field, where heads were collected for testing for resistance to embryo damage. Additionally, one head from each plot was inoculated with loose smut (incited by Ustilago nuda) for assessment in the greenhouse. Hydration index measurements were completed on the full diversity panel in the micro-malter, where hydration was measured at 48, 72, and 96 hours into the malting process. These data will be used to conduct GWAS and select lines for future malting studies. Goal 4: Development of the modified NAM population began at all locations. Each location selected five parental lines to cross to the three common parents (Buck, Purple Prince, and MS10S4111-01). Selection of individual parents was made based on traits important for organic growing conditions or end-use quality. Despite some issues with crossing, nearly all crosses were made successfully and F1 plants were grown out. Working with the USDA-ARS lab at Pullman, WA, we developed a marker set using GMS sequencing that will be used for marker-assisted selection at the F2 plant stage. All groups will be ready to grow out F2 plants this fall/winter for tissue collection. Goal 5: 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. The naked barley composite population was grown in two locations in Davis, CA. Selections were made from each location, which will be grown the following season at both locations again as well as a few K-12 school gardens. Karl Kunze (PhD student at Cornell) was able to go into the classroom and taught a high school agriculture course on concepts of plant breeding. 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, UW-Madison, and UC Davis were able to hold in-person field days. **PUBLICATIONS (not previously reported):** 2020/09 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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Intensifying Organic Grain Production: Balancing Production and Conservation Goals

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Project No.	PENW-2020-02139
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Performing Institution	PENNSYLVANIA STATE UNIVERSITY, 408 Old Main, UNIVERSITY PARK, PENNSYLVANIA 16802-1505

NON-TECHNICAL SUMMARY

Our long-term research goal is to support the adoption of coupled reduced-tillage and cover cropping practices that facilitate the intensification of domestic organic grain production without compromising environmental quality and economic viability of organic farms. Our long-term extension-outreach goal is to facilitate the increase in knowledge of sustainable intensification practices by fostering peer-to-peer learning via existing organic grower networks and other outreach activities. We propose a cropping system experiment that will quantify tradeoffs among provisioning, regulating, and supporting services within experimental systems that use alternative cover cropping and reduced-tillage practices. Experimental systems will differ in tillage intensity, tillage frequency and perenniality with a 3-yr grain rotation. We will also conduct a pattern-based study of 30 organic grain farms to determine the relationship between soil health, tillage intensity, tillage frequency, perenniality, and other cash and cover crop management practices. Three farmer cases studies will support on-station and on-farm research objectives. Outreach programs and materials will be informed, developed, and delivered to a broad audience by the project team, farmer cooperators, and advisory board comprised of organic grain farmers, Extension educators, and representatives of governmental agencies, NGOs, and the organic grain industry through a variety of means, including interactions with three organic crop grower networks. Effectiveness of all extension products and activities will be evaluated. This project is appropriate for funding by OREI because it addresses the development and improvement of organic production; potential economic benefits of organic production; advanced on-farm research; and optimal conservation and environmental outcomes from organically produced products.

OBJECTIVES

Our long-term research goal is to support the adoption of coupled reduced-tillage and cover cropping practices that facilitate the intensification of domestic organic grain production without compromising environmental quality and economic viability of organic farms. Our long-term extension-outreach goal is to facilitate the increase in knowledge of sustainable intensification practices by fostering peer-to-peer learning via organic grower networks and other outreach activities. To accomplish these goals, we will integrate on-station research with farmer-participatory research on organic farms in consultation with our project advisory board comprised of organic grain

farmers, extension-educators, representatives of government agencies, NGOs and the organic grain industry. Research Objective (O1): Quantify differences among experimental systems that employ alternative reduced-tillage and cover cropping practices on agronomic (cash crop yield and quality, soil fertility, annual and perennial weed dynamics, insect pest damage, plant disease damage, biological control potential), environmental (soil erosion potential, soil health indicators, nitrate leaching) and economic (net returns) outcomes. Research Objective (O2): Quantify the relationships between tillage intensity, tillage frequency, perenniality, days of living cover, soil fertility amendments, grain intensity (i.e., proportion of total acres in grain production) and soil health indicators (physical, chemical, biological) via participatory research on 30 organic or transitioning grain farms. Extension Objective (O3): Foster co-learning in regional organic grain producers\' networks about the benefits and challenges of alternative reduced-tillage and cover cropping practices (O1) via development of co-learning events at farms participating in observational studies (O2), production of three case-studies of farms participating in observational studies (O2-O3), and facilitation of other co-learning opportunities for organic growers, transitioning grain farmers, and agricultural service providers (O3).

APPROACH

Our approach includes four interconnected activities: experiment station research (O1), a multi-year observational study at 30 organic farm locations (O2), three case studies of farms participating in O2 (O3), and co-learning events for participating growers, grower networks, agricultural service providers, transitioning farmers, and project staff (O3). O1: On-station cropping system experiment. To investigate the relative performance of corn - soybean - winter wheat rotations that utilize alternative reduced-tillage and cover cropping practices, we will conduct an experiment on 4.0 hectares of certified organic land at RELARC. The experimental cropping system treatments will include three corn - soybean - wheat rotations that are managed with alternative tillage practices preceding cash crops. The Standard-Till (S1) system will use inversion (n = 2) and non-inversion (n = 1) tillage, representing tillage practices comparable to commercial farms in the Northeast. The Shallow-Till (S2) system will use shallow, non-inversion tillage (n = 3) using a high-speed disk, which is an emerging practice in organic grain systems. The Reduced-Till (S3) system will use no-till (n = 2) and inversion-tillage (n = 1) practices, which integrates no-till planting practices that we have developed for soybean and winter grain production. Each of these rotations integrates a cover crop between cash crops using establishment methods that are compatible with tillage practices within the rotation sequence. The fourth experimental cropping system will include a 3-yr perennial, alfalfa-grass sequence (Perennial; S4), with 1st year alfalfa-grass initiated following winter-wheat in each crop entry point. O2: On-Farm Soil Health Benchmark Study. In collaboration with PASA\'s education and on-farm research program, we will conduct a pattern-based observational study to explore relationships between tillage intensity, days of living cover, grain intensity, fertility management, and soil health indicators. To accomplish this objective, we will extend PASA\'s Soil Health Benchmark Study (SHBS) framework to 30 established or transitioning organic grain farms in the Northeast. O3: Extension-Outreach Objectives. Our extension-outreach objectives are based on two observations: (1) established organic farmers continue to express that they value participatory learning environments where they can learn from each other because they trust that other farmers have learned through experience, and (2) there is increasing need to produce extension-outreach materials targeting transitioning grain farmers and agricultural service providers that provide details on BMPs for weed control, nutrient management, soil-health, and soil-conservation in organic systems. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Our target audience is comprised of Pennsylvania and Mid-Atlantic organic grain growers, and prospective organic grain growers. We also engage with Extension educators, governmental agencies, NGOs, and the organic grain industry at large. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?In summer 2024, one M.Sc. student (S. Tillotsen) successfully completed her graduate program and published a thesis, which is currently being advanced towards manuscript publication. A second graduate student, L. Wellman, has transitioned from an M.Sc. student to a Ph.D. student and is currently drafting manuscripts based on research conducted within this project. In 2024, we employed three undegraduate students that worked within this project. Finally, we hosted two undergraduate classes at the experimental site to provide training on organic agriculture. How have the results been disseminated to communities of interest?In 2024, we hosted or participated in X outreach events that highlighted the results from this project. Outreach targeted organic grain producers as well as agricultural professionals in organic support industries. Finally, we hosted an Argentinian delegation of agronomists and farmers at the site to share research goals and outcomes. What do you plan to do during the next reporting period to accomplish the goals?Prior to August 2025, we plan to publish 4-6 manuscripts that summarize this work. We will also incorporate our findings into the updated Penn State Organic Crop Production Guide. Impacts What was accomplished under these goals? In 2023, we completed our third crop production year of the three-year rotation experiment. In 2024, we planted the entire experimental site to sorghum sudangrass to complete a phytometer experiment, which allows for detection of soil and pest management legacies across experimental systems and crop entry points. In 2024, we continue to advance data summary and analysis of the three-year

cropping systems experiment towards publication. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Barbercheck, M., Ahmad, I. 2024. Conservation of Soilborne Entomopathogenic Fungi in Agroecosystems. Invited symposium presentation, Advancement and Future of Microbials as Part of Integrated Pest Management. Entomology 2024, Phoenix, AZ. 10 13 Nov. 2024. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Ahmad, Imtiaz, Jim&#65533;nez-Gasco, Mar&#65533;a del Mar, Barbercheck, Mary E. 2023. Going underground: Endophytic entomopathogenic fungus - insect phytopathogen - plant interactions. Invited talk in symposium: Life is Interesting: Multi-species Interactions Spanning Diverse Kingdoms. Entomology 2023, Nov. 5 8, National Harbor, MD. Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Ahmad, I., M. d. M. Jimenez-Gasco, and M. E. Barbercheck. 2024. \"Water Stress and Black Cutworm Feeding Modulate Plant Response in Maize Colonized by Metarhizium robertsii\" Pathogens 13 (7): 544. https://doi.org/10.3390/pathogens13070544 Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Regan, K.H., Voortman, C.A., Barbercheck, M.E. 2024. Seedcorn maggot response to planting date, cover crops, and tillage in organic cropping systems, Journal of Economic Entomology 117: 555563, https://doi.org/10.1093/jee/toae026 Type: Book Chapters Status: Published Year Published: 2024 Citation: Barbercheck, M. 2024. Conservation of Entomopathogenic Nematodes in Agroecosystems, Ch. 29 in: Shapiro-Ilan, D. and Lewis, E.E.(Eds.) Entomopathogenic Nematodes as Biological Control Agents. CABI, Wallingford, Oxfordshire, England Type: Websites Status: Published Year Published: 2024 Citation: Barbercheck, M., A. Hodgson, A. Isaacson. 2024. Seed cleaning at Provident Farms. Field Crop News. 20 February 2024. https://extension.psu.edu/seed-cleaning-at-provident-farms?j=779688&sfmc_sub=35519620&l=159_HTML&u=20859616&mid=7234940&jb=2001&utm_medium=email&utm_source=MarketingCloud&utm_campaign=FAFC_2024_FEB_22_GN_EM_FIELDCROPNEWS&utm_content=FAFC_2024_FEB_22_GN_EM_FIELDCROPNEWS&subscriberkey=0030W00003P0ySiQAJ Progress 09/01/22 to 08/31/23 Outputs Target Audience:Our target audience is comprised of Pennsylvania and Mid-Atlantic organic grain growers, and prospective organic grain growers. We also engage with Extension educators, governmental agencies, NGOs, and the organic grain industry at large. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?This year, one Ph.D student (weed science) and one Masters student (entomology) participated in ROSE data collection and conducted their own research on the site. We supported three undergraduate research interns between the weed science and entomology branches of this project. One staff member who provided integral support to ROSE has secured an extension education job in eastern Pennsylvania. How have the results been disseminated to communities of interest?We made five publications on ROSE data this year, including a 23-page booklet on organic no-till soybean production. Its associated webpage went live in late August, and we got 18 unique pageviews that month, plus 42 in September and 204 in October. We made seven academic conference presentations on ROSE data.We conducted 13 workshops or class lectures featuring ROSE data. What do you plan to do during the next reporting period to accomplish the goals?In the next reporting period, we anticipate we\'ll: 1. Analyze the three years of data over the 23-24 winter. 2. Develop publications and presentations associated with the final conclusions of some aspects of the ROSE project, including at organic grower network meetings. 3. Conduct the fourth year of field research. We\'ll gather final data on weed seedbanks and soil health, and plant all plots to corn to measure the overall legacy effect of all treatments. Impacts What was accomplished under these goals? Research Objective (O1).Our experimental design allows us to compare alternative 3-yr crop sequences that range in tillage intensity and frequency as well as alternative management practices within cover crop/cash crop sequences. Our multidisciplinary approach allows us to compare system performance (S1-S4) using multiple indicators of sustainable intensification (pest suppression, nutrient balance, soil health, grain production, net returns). We expect that cropping systems designed to significantly lower tillage intensity and frequency (S2-S3) will increase environmental performance (e.g., improved soil health and lower N loss) compared to standard tillage practices (S1) but will result in more variable levels of weed suppression, grain yields, and short-term net profits. In 2023, we completed our third crop production year of the three-year rotation experiment. We analyzed data collected in 2021 and 2022 and presented preliminary trends in a variety of contexts. Our shallow-till system is now demonstrating soil compaction near the surface, lower yields, and lower soil aggregate stability and respiration compared to other treatments. Our corn yields were 79 to 93 percent of the county average (conventional) in our first two years across all treatments, and our soybean yields were 67 to 90 percent. Our wheat yields were 58 percent of statewide conventional yields in our first two years of the study. Research Objective (O2).We continue to analyze the results of the PASA Sustainable Agriculture Soil Health Benchmark Study, which we previously recruited farmers to participate in. Our approach empowers farmers to monitor their own soil, share experiences with peers during co-learning events, and make changes to farming practices in response to their monitoring efforts. Extension Outreach Objective (O3). We\'ve been distributing our information via co-learning events, like winter grower network meetings, where organic crop producers meet to exchange ideas. In 2023, ROSE team members conducted 6 learning events where we discussed preliminary results of ROSE in a co-learning format. We also produced an organic no-till soybean production guide and

distributed it to interested parties. Publications Type: Journal Articles Status: Published Year Published: 2022 Citation: Ahmad, I., M.d.M. Gasco-Jimenez, D. S. Luthe, M. Barbercheck. 2022. Endophytic Metarhizium robertsii suppresses the phytopathogen, Cochliobolus heterostrophus and modulates maize defenses. PLoS ONE 17(9): e0272944. Type: Journal Articles Status: Accepted Year Published: 2023 Citation: Regan, K., Voortman, C., Barbercheck, M. Seedcorn Maggot Response to Planting Date, Cover Crops, and Tillage in Organic Cropping Systems. In press: Ms. \# ECONENT-2023-0198. Type: Journal Articles Status: Accepted Year Published: 2023 Citation: Peterson, H., Ahmad, I., Barbercheck, M. 2023. Maize response to endophytic Metarhizium robertsii is altered by water stress. PLoS One: In Press. MS# PONE-D-23-14413 Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Ahmad, Imtiaz, Jim&#65533;nez-Gasco, Mar&#65533;a del Mar, Barbercheck, Mary E. 2023. Going underground: Endophytic entomopathogenic fungus - insect phytopathogen - plant interactions. Invited talk in symposium: Life is Interesting: Multi-species Interactions Spanning Diverse Kingdoms. Entomology 2023, Nov. 5 8, National Harbor, MD. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Ahmad, I.; Jim&#65533;nez-Gasco, M.d.M.; Barbercheck, M. E. Endophytic Metarhizium robertsii suppresses the phytopathogen, Cochliobolus heterostrophus and modulates maize defenses. 2023 International Congress on Invertebrate Pathology and Microbial Control & 55th Annual Meeting of the Society for Invertebrate Pathology, July 30 - August 3, 2023, University of Maryland, College Park, MD Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Barbercheck, M., Ahmad, I., Jim&#65533;nez-Gasco, M. d..M. Going underground: Digging up the dirt on Metarhizium-plant-pest interactions in an organic cropping system. USDA NIFA: OREI & ORG Project Directors Meeting, April 19th and 20th, 2023, Washington, DC Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: Wallace J, Barbercheck M, Bay Nawa S, Bilenky M, Borelli K, Cornelisse S, Egan F, Hamilton, Hartman D, Hodgson A, Hoover R, Isbell S, Mazzone T, Murillo-Williams A, Tillotson S, Voortman C, Wellman L, White C. Intensifying organic grain production: balancing production and conservation goals. USDA NIFA: OREI & ORG Project Directors Meeting, April 19th and 20th, 2023, Washington, DC Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Wellman, L. 2023. Weed Potential of Roll-Crimped Cereal Rye Differs Across Cultural Practices. Weed Science Society of America/Northeast Weed Science Society conference, Jan 30, 2023, Arlington, VA Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Wellman, L. 2023. Weed Potential of Roll-Crimped Cereal Rye Differs Across Cultural Practices. ASA, CSSA, SSSA International Annual Meeting, Oct. 30, 2023, St. Louis, MO Type: Websites Status: Published Year Published: 2023 Citation: Hamilton, A., Wallace, J., Barbercheck, M., Curran, W. 2023. Organic No-till Soybean Guide. https://extension.psu.edu/organic-no-till-soybean-production-in-pennsylvania-is-it-for-you Type: Websites Status: Published Year Published: 2023 Citation: Bilenky, M., Wallace, J. Barbercheck, M. 2023. Tillage and cover crop management practices on Pennsylvania organic grain farms. PSU Extension Fact Sheet. EE0824 https://extension.psu.edu/tillage-and-cover-crop-management-practices-on-pennsylvania-organic-grain-farms Progress 09/01/21 to 08/31/22 Outputs Target Audience:Our long-term research goal is to support the adoption of coupled reduced-tillage and cover cropping practices that facilitate the intensification of domestic organic grain production without compromising environmental quality and economic viability of organic farms. Our long-term extension-outreach goal is to facilitate the increase in knowledge of sustainable intensification practices by fostering peer-to-peer learning via existing organic grower networks and other outreach activities. We propose a cropping system experiment that will quantify tradeoffs among provisioning, regulating, and supporting services within experimental systems that use alternative cover cropping and reduced-tillage practices. Experimental systems will differ in tillage intensity, tillage frequency and perenniality with a 3-yr grain rotation. We will also conduct a pattern-based study of 30 organic grain farms to determine the relationship between soil health, tillage intensity, tillage frequency, perenniality, and other cash and cover crop management practices. Three farmer cases studies will support on-station and on-farm research objectives.Outreach programs and materials will be informed, developed, and delivered to a broad audience by the project team, farmer cooperators, and advisory board comprised of organic grain farmers, Extension educators, and representatives of governmental agencies, NGOs, and the organic grain industry through a variety of means, including interactions with three organic crop grower networks. Effectiveness of all extension products and activities will be evaluated. This project is appropriate for funding by OREI because it addresses the development and improvement of organic production; potential economic benefits of organic production; advanced on-farm research; and optimal conservation and environmental outcomes from organically produced products. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?In 2022, two M.Sc. graduate students (Weed Science, Entomology) have participated and developed research thesis projects. One post-doctoral research associate (Bilenky) has led coordiation of research and extension objectives and has accepted a tenure-track faculty position (Jan 2023) that will focus on sustainable vegetable crop production at Purdue University. We have also supported two undergraduate research interns, one of which has secured college-level funding to develop a research project within our cropping systems experiment. Four undergraduate interns participated in execution of Pasa\'s Soil Health Benchmark study. How have the results been disseminated to communities of interest?Preliminary results

have been shared with organic grower networks in three differet winter workshops. What do you plan to do during the next reporting period to accomplish the goals?In the next reported period, we anticipate (1) sharing research results at Pasa annual conference (Februrary 2023); (2) publishing final case-study products (fact sheet, videos) on Penn State\'s extension platforms; (3) continue to engage stakeholders at organic grower network meetings (n = 3); and (4) host a field day during Ag Progress Days (August 2023). Impacts What was accomplished under these goals? Research Objective(O1). Our experimental design will allow us to compare alternative 3-yr crop sequences that range in tillage intensity and frequency as well as alternative management practices within cover crop/cash crop sequences. Our multidisciplinary approach will allow us compare system performance (S1-S4) using multiple indicators of sustainable intensification (pest suppression, nutrient balance, soil health, grain production, net returns). We expect that cropping systems designed to significantly lower tillage intensity and frequency (S2-S3) will increase environmental performance (e.g., improved soil health and lower N loss) compared to standard tillage practices (S1) but will result in more variable levels of weed suppression, grain yields, and short-term net profits. In 2022, we completed our second crop production year of the 3-yr crop rotation experiment. A broad multi-criteria assessment has been employed, and participating lab groups (Agronomy/Weed Science, Entomology/Soil Health, Plant Pathology, Economics) are processing, analyzing and synthesizing data sets. Based on the first two years, our data suggests that undersown clover followed by full inversion tillage significantly increases corn yields relative to other reduced-tillage practices. However, no-till soybean production has resulted in comparable yields to tillage-based soybean production practices. Alternative tillage practices has produced variable results for winter wheat production. Detailed analysis of weed community trajectories, early season insect pest and predator dynamics, crop seedling disease estimates, short-term indicators of soil health, and net returns to production have yet to be fully synthesized. Research Objective(O2).Our pattern-based observational study is designed to quantify relationships between tillage intensity and frequency, crop rotation sequences, fertility management, and soil health indicators. This approach will allow us to identify combinations of organic management practices that result in similar or dissimilar soil health outcomes. We recruited 18 organic grain farms in fall of 2021 and 30 farms in fall of 2022 to participate in PASA Sustainable Agriculture\'s Soil Health Benchmark Study.Participating farmers have placeda high-value on co-learning activities associated with the PASA-SHBS and organic grower networks. Our approach empowers farmers to monitor their own soil, share experiences with peers during co-learning events, and make changes to farming practices in response to their monitoring efforts.Analysis of relationships between soil health scores and farming practices is on-going. Extension Outreach Objective (O3).We expect members of two established aregional organic crop producers\' network, including our farmer-cooperators, will adapt information shared at co-learning events (winter grower network meetingsandtwilight meetings) to incorporate reduced tillage and cover cropping practices in their farm operation. In 2022, project team members faciliatated and participated in two winter organic grower network meetings and a twilight meeting, where aspects of project goals were discussed in a co-learning format. In addition, three case studies highlighting organic grain farms and their perspectives on soil-health building practices were completed. Currently, six videos have been completed and will be hosted on extension web pages in the spring of 2023. Publications Type: Other Status: Published Year Published: 2022 Citation: Barbercheck, M.E., Borrelli, K. A., Wallace, J. 2022. Organic Crop Production. Part 1, Section 11. Penn State Agronomy Guide. AGRS-026 Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Peterson, H., Barbercheck, M. 2022. Impact of Water Stress on the Establishment and Persistence of Endophytic and Entomopathogenic Metarhizium robertsii. Eastern Branch ESA Meeting, Feb. 19-21, Philadelphia, PA Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Regan, K., Voortman, C., Barbercheck, M. 2022. Seedcorn maggot response to planting date, cover crops, and tillage in organic cropping systems, 20022 ESA, ESC, and ESBC Joint Annual Meeting. Vancouver, B.C. Canada, Nov. 13-16, 2022 Type: Journal Articles Status: Published Year Published: 2021 Citation: Wallace JM, Barbercheck ME, Curran W, Keene CL, Mirsky SB, Ryan M, VanGessel MJ (2021) Cover crop-based, rotational no-till (CCORNT) management tactics influence crop performance in organic transition within the Mid-Atlantic US. Agronomy Journal. 113:5335-5347. https://doi.org/10.1002/agj2.20822 Type: Journal Articles Status: Published Year Published: 2021 Citation: Champagne RJ, Wallace JM, Curran WS, Barbercheck ME (2021) Rotational no-till and tillage-based organic corn produce management tradeoffs in the Northeast. Agronomy Journal, 113(6), 5348-5361. https://doi.org/10.1002/agj2.20823 **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience: Nothing Reported Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project team recruited (1) one M.Sc. student (Fall 2021), one post-doctoral research associate (May 2021), and two undergraduate interns (summer 2021) to participate in research-extension activities associated with the cropping systems experiment (RO1).Four undergraduate interns have been recruited to participate in on-farm soil sampling associated with RO2. How have the results been disseminated to communities of interest? First year results are in the process of summary and will reported in 2022. What do you plan to do during the next reporting period to accomplish the goals? In the next reporting period, we anticipate disseminating survey results and case study videos through multiple outreach mediums. Preliminary data from on-station (RO1) and on-farm (RO2) will be summarized and shared at extension-outreach

events. **Impacts** What was accomplished under these goals? Research Objective (O1): Cropping systems experiment was initiated in 2020 and the first production year (2021) has been completed. Protocols have been developed and executed to document agronomic (yield, quality, soil fertility, weed dynamics, insect pest damage, plant disease, biological control potential) and environmental (soil erosion potential, soil health indicators) metrics among alternative cropping systems. Research Objective (O2): In January 2021, a mailed survey of registered organic grain producers (n = 450) in Pennsylvania was completed to collect information on crop production practices and demographics, and to recruit farms to participate in the soil health benchmark study. Survey response was high (n = 110). A report on tillage production and cover cropping practices among organic grain growers is in preparation and 25 farms have been recruited to participate in on-farm research. Soil sampling at these farms was initiated by collaborator Pasa Sustainable Agriculture in October 2021. Research Objective (O3): In the 2021 growing season, three farmer case studies were developed and executed. Farmer interviews were transcribed, video footage was edited and storyboards were developed. Final editing of case study videos is ongoing, with anticipated completion in February 2022. Organic grower network meetings have been scheduled at two locations for February 2022. **Publications**

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Decision Support to Reduce the Nitrogen Yield Gap in Organic Agriculture

Accession No.	1023590
Project No.	PENW-2020-02125
Agency	NIFA PENW\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51300-32178
Proposal No.	2020-02125
Start Date	01 SEP 2020
Term Date	31 AUG 2023
Grant Amount	$500,000
Grant Year	2020
Investigator(s)	Kaye, J. P.; White, CH, M.; Finney, DE, M..
Performing Institution	PENNSYLVANIA STATE UNIVERSITY, 408 Old Main, UNIVERSITY PARK, PENNSYLVANIA 16802-1505

NON-TECHNICAL SUMMARY

One of the challenges that farmers face is deciding which fertilizers to use and how much to apply to their fields. Fertilizers provide essential nutrients for healthy crops and can increase yields and profits.Nitrogen is an important plant nutrient and component of most fertilizers.Too little nitrogen stunts crop growth, but too much can cause excessive weed pressure and nitrogen losses to the environment.Excess nitrogen in drinking water can make it unsafe for human consumption and excess nitrogen in lakes and streams can be detrimental to aquatic life and human recreation.Although most crops require supplemental nitrogen for optimum growth, some nitrogen can be supplied from the soil and plant residues.Some farmers grow cover crops from fall to spring and as these plants decompose, they can be a source of nitrogen.However, this existing fertility depends on soil and cover crop characteristics specific to each farm field.To date, no nitrogen decision support tool has enabled organic farmers to calculate the nitrogen that will be released slowly from the soil and decomposing cover crops on their fields during the growing season.Without this knowledge, organic farmers are left to use rules of thumb to estimate existing fertility, often leading to both over and under applications of fertilizer.We have developed an onlinetool that predicts corn yield based on the amount of nitrogen that is slowly released from the soil and decomposing cover crops.Using site-specific information, the tool calculates the amount of nitrogen needed to supplement the existing soil fertility and to achieve a goal for corn yield.Through this project we will expand the testing our tool to corn fields across Pennsylvania with a wide variety of soil types and cover crops.Also, we will use laboratory experiments to expand our understanding of how soil microbes slowly release nitrogen, making it available to plants. These laboratory studies will help us predict the conditions under which the model will work well.We will work with a small group of farmers to test the tool on their fields to make sure it is easy to use and helpful in making fertilizer decisions.We plan to improve the tool by adding the capability to compare the costs of different nitrogen fertilizer options, allowing farmers to consider profitability in their decision-making.Ultimately our goal is to provide a nitrogen decision support tool that assists organic farmers in choosing the optimal type and amount of fertilizer for their fields, maximizing profitability for farmers and improving environmental quality.

OBJECTIVES

One of the grand challenges in organic agriculture is managing nutrient recycling to support high cash crop yields. Soil organic matter (SOM) and decomposing cover crops can contribute to the nitrogen (N) requirements of cash crops, offsetting the need for manure or other organic fertilizer applications. We have developed a model that predicts unfertilized corn yield, based on the N contributions of SOM and decomposing cover crops. This model has been integrated into an N decision support tool, which calculates the supplemental N fertilizer requirements for organic grain and silage corn in Pennsylvania. Our goal is to advance our decision support tool to widespread use, allowing Pennsylvania farmers to manage N fertility to increase yields and profits.The main objectives for this proposal are:Objective 1. Agronomic validation: Test our model for predicting the N fertilizer requirements for corn in PA on a wider range of sites. The sites in the dataset used to calibrate the current model had medium to fine-textured soils and moderate SOM levels. Here we add fields (both from commercial farms and our research station) with coarser soil textures and SOM lower and higher than we have previously tested. We will use these sites to test the accuracy of our existing model and to refine the model as necessary. This process will ensure our model\'s accuracy for predicting the N fertilizer requirements for corn fields in Pennsylvania across a wide variety of soil textures, soil organic matter levels, and cover crop C:N ratios.Objective 2. Biogeochemical validation: Test parameters in the system of equations that underlie our model. In the equations that predict the N fertilizer requirements, some parameters have fixed values based on assumptions, like the microbial biomass and soil organic matter C:N ratios, while others are calibrated, like the humification efficiency (e). The assumed and calibrated parameters are vulnerable points for extrapolation so we propose experiments that will test these parameters using soils with varied texture and SOM. We expect that variation in C:N ratio of microbial biomass and soil organic matter are small, such that site-specific estimates of these parameters are not required as we expand the application of this decision support tool. On the other hand, variation in humification efficiency will be large, but predictable based on soil texture and residue C:N ratio, such that these parameters can be adjusted based on site-specific measurements.Objective 3: Bring our N decision support tool into use through multi-faceted outreach.We will advance our prototype decision support tool(<https://extension.psu.edu/nitrogen-recommendations-for-corn>) to include not only N fertilizer requirement calculations but profitability implications of choices among fertilizer options. Farmers or other agricultural professionals will need to provide values for a few site-specific variables (soil texture, SOM, N content and C:N ratio of cover crops, and the yield goal) and the toolwill generate an output of the recommended quantity of N fertilizer and the cost of using different N sources to meet this requirement. We will engage in several outreach activities to introduce our tools to farmers and other agricultural professionals. Outreach activities will include events (meetings with our advisory board and grower networks, workshops and on-farm field days) and materials (an updated PAAgronomy Guide, PA Organic Crop Production Guideand fact sheets) to facilitate the use of our N decision support tools. We expect our tools will be used by growers, extension educators, other trainers, and agriculture-related organizations to determine N fertilizer requirements for organic corn grown in Pennsylvania.

APPROACH

Objective 1. Agronomic validation:The agronomic validation experiment will occur in the first year of the project and will involve field experiments at one research station and two commercial farms. These sites were selected because they have soils with coarser textures and higher and lower levels of SOM than the sites used to develop the model. The data collected will allow us to test the accuracy of our current model for a wider range of sites and also to recalibrate the model if necessary.In the fall, we will establish plots in preparation for the following growing season. At our research station, we will plant four replicate blocks, each containing 12cover crop plots (triticale, canola, radish, oat, and clover plus several cover crop mixtures of 2, 3, 4, or 6 species). At the two on-farm sites, we will plant 4 replicate blocks, each containing 3 cover crop plots (one each of grass, legume, and grass:legume mix). At the time of cover crop planting, we will collect soil samples and analyze for texture, SOM, total C, total N and extractable inorganic N. We will also submit these samples for a standard soil fertility test (pH, extractable P and K) to ensure that fields are near optimal levels that will not constrain yields. Prior to the first hard frost, we will measure fall cover crop biomass by species in 2 small quadrats (0.5 m x 0.5 m) per plot by clipping, drying and weighing the biomass. The N concentration of each cover crop species will be measured.Just prior to cover crop termination in spring, cover crop biomass and its N concentration will be measured by species in small quadrats. In addition, the spring normalized difference vegetation index (NDVI) of the cover crops will be measured with a handheld Greenseeker sensor, which can be used as a way to estimate the cover crop biomass N content using calibration equations that we developed.After cover crop termination, incorporation, and corn planting, supplemental N fertility plots will be established in a split-plot design to assess the corn responses to supplemental nitrogen. Four N addition levels will be established: no supplemental N, supplemental N recommended by the current version of our decision support tool, and rates that are 50% and 150% of what the tool recommends. The N additions will be made with poultry feather meal (13-0-0) because it isolates the effect of N, is commercially available, and has well-documented availability levels.At harvest time, corn plants in the sampling strip will be hand cut just above the brace roots, and ears will be separated from the rest of the plant.

These two samples (ears and rest of plant) will be separately weighed and ground in a wood chipper and random samples of the chips will be dried and analyzed for N concentration.Objective 2. Biogeochemical validationAs we apply our approach in a wider range of soil textures and SOM levels, it is important to test whether site to site variation in key model parameters will compromise extrapolation. Our model uses some assumptions about microbial stoichiometry and physiology; namely that the average microbial biomass C:N is 10:1 and that the microbial C:N is the same as the soil organic matter C:N. We will test these assumptions by measuring microbial and soil organic matter C:N ratios in soils collected from farms throughout PA. In addition, we will assess how humification efficiency (ε) varies across farms and in response to soil texture and cover crop C:N.To test the sensitivity of our model to the assumption that the C:N ratio of soil (C:Ns) and microbial biomass (C:Nm) are comparable and \~10, we will measure soil and microbial C:N across a wide range of organic farms: 10 commercial farms and 1 research station. Soil will be collected from two fields at each farm to increase the diversity of soil types. Because of our past research on these farms, we know that our dataset will span a much wider range of SOM and texture that the soils used to develop the model. The C:Nm will be determined by chloroform fumigation extraction and the C:Ns will be determined by combustion analysis.Humification efficiency (ε) is similar in concept to the microbial carbon use efficiency (CUE- the proportion of decomposed C that microbes use to build microbial biomass), however ε is the long-term outcome of multiple microbial generations. Using the same soils from the 11 organic farms, humification efficiency (ε) will be determined using 13C-glucose tracing. Our method is based on a standard approach to measuring community-level CUE, modified to incorporate the temporal component of ε and humification into microbial biomass and SOM.To isolate the effect of texture on ε, we will use a manipulative experiment using soils from the PSU research station. We will collect high-clay soil and recover (by sieving) sand from the soil. The recovered sand will be added incrementally to samples drawn from the original fine-textured soil to create a texture gradient that spans the entire range at the site. We will measure CUE and ε using the same glucose 13C tracer method.To determine the effect of cover crop C:N on ε we will incubate soil from the research station with litterbags of 13C labeled cover crop residue (created by be growing cover crops in a sealed greenhouse chamber with in a 13CO2 enriched atmosphere) in 16 oz. glass mason jars. We will create a gradient of cover crop residue C:N using grass (triticale) and legume (crimson clover) cover crops and mixtures thereof. Litter bags will be destructively harvested at 2, 6 and 12 weeks and analyzed for %C and 13C (combustion followed by isotope ratio mass spectrometry). The 13C of microbial biomass carbon will be determined by persulfate digestion of 0.5M K2SO4 extracts. Using these data, ε for each soil and cover crop treatment equals 13C in microbial biomass divided by 13C mass loss from the litterbag.Objective 3: OutreachWe will advance our prototype decision support tool to include not only N fertilizer requirements, but profitability implications of N fertilizer choices. Yield response curves (developed from N additions as part of Objective 1) will be utilized for partial budgeting analysis to assess the economic implications of N management choices.Partial budgeting analysis is a standard technique for comparing changes in profitability resulting from a change in the production process. Yield variation, commodity prices, fertilizer or manure prices and costs of their application will be combined to calculate the economic return of various N fertilizer options.In the first year of the project, farmers on our advisory board and farmers involved in the Central Susquehanna Valley Organic Crop Producers Network will meet to vet ideas regarding the visualization, inputs, and outputs of the web dashboard interface and the accompanying pen and paper worksheets. In these meetings, we will facilitate participants using real data from their farms to calculate N fertilizer recommendations. Through group discussions and evaluations, we will identify stumbling blocks to using the tool and solicit feedback for improvement to implement in year 2. In year 3 of the project, we will assemble the same groups to review results from the research and revisions to the dashboard. Progress 09/01/20 to 08/31/24 Outputs Target Audience:The goal of our project is to develop a nitrogen (N) decision support tool suitable for calculating the N fertilizer requirement for any corn field in Pennsylvania. Accordingly, Pennsylvania farmers growing corn were our primary target audience. In addition, consultants, extension educators and any agricultural professionals who assist with making N fertilizer decisions would be included among those we seek to reach through our outreach activities. Through presentations/posters at a number of events/webinars we introduced the N decision support tool to a diverse group of agriculture professionals in Pennsylvania and other states as well as members of environmental/conservation NGOs and regulatory agencies. To help us test and improve the N tool, we met annually with our advisory board to vet ideas regarding the visualization, inputs, and outputs of the web dashboard interface. We worked closely with many of the farmers in this group through previous research and extension activities and they have indicated a strong interest in continuing to work with us to develop our N decision support tool. These farmers are distributed geographically across Pennsylvania and southern New York. Several are involved with farmer network groups (including the Central Susquehanna Valley Organic Crop Producers Network. Another target audience includes students with an interest in a career in organic agriculture. As noted above in the professional development section, 10 undergraduate students and 2 graduate students worked directly on this project. A final target audience was scientists interested in nitrogen decision support. We reached scientific audiences through peer reviewed publications (see \"publications\" section) presentations at the ASA-CSA-SSSA meetings.the Penn State Plant Science seminar (January 2023) and the Penn State

Undergraduate Exhibition. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Ten undergraduate students participated in agricultural research through assisting with field and laboratory work for this project. Four undergraduates led independent research related to the N tool development, which provided opportunities to communicate with farmers and present posters at a scientific conference and an exhibition at Penn State. At Penn State, undergraduates participated in the development of a cover crop lookup table, measuring soil respiration rates across a soil texture gradient, and estimating carbon credits at the Penn State research station. At Ursinus, an undergraduate student wrote an honors thesis on communication strategies in agricultural science. Two graduate students, two laboratory technicians and a postdoctoral scholar helped to train and mentor the undergraduate students in their research experiences. We included these students in lab group meetings, which provided opportunities to listen to presentations by graduate students, discuss scientific journal articles, review draft manuscripts/presentations, and view preliminary datasets that they had helped to collect. The two graduate students (PhD candidates) used a component of this project as part of their dissertation research. Most of our project team members had several opportunities to present data collected as part of this project and to participate in outreach events. How have the results been disseminated to communities of interest?We documented our dissemination activities in by entering them all as \"other products/outputs\". Here we highlight some examples. We met with our farmer advisory board once per year in all years of the project. Members of our project team have presented \>20 talks or posters at outreach events in which the N decision support tool was introduced to agricultural professionals in Pennsylvania and other states. We contributed to the PASA 2021 Virtual Sustainable Agriculture Conference with a recorded presentation about the principles that regulate N availability from cover crops and soil organic matter along with a demonstration of our web-based N decision support tool. This annual event typically brings together over 2,000 growers, buyers, distributors and consumers. A complete list of events is provided in the Other Products/Outputs section. We reached scientific audiences through peer reviewed publications (see \"publications\" section) presentations at the ASA-CSA-SSSA meetings (November 2022), the Penn State Plant Science seminar (January 2023) and the Penn State Undergraduate Exhibition (April 2023). These events allowed us to present our testing and recalibration of the biogeochemical equations underlying the N tool. We also hosted a workshop for 22 high-school students as part of the Pennsylvania School for Excellence in the Agricultural Sciences. Students visited the Penn State research station to learn about cover crops and participated in a hands-on experience processing soil samples in our campus laboratories. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? ??Through this project we tested our nitrogen decision support tool on corn fields across Pennsylvania with a wide variety of cover crops and soil types. The original equations used to calculate fertilizer recommendations were developed for fine to medium-textured soils. Through this project we expanded our input dataset to include sites with coarser-textured soils and recalculated the equations. We tested the accuracy of the equations for predicting corn yield with field research at our research station in central Pennsylvania and commercial farms. In addition, we performed laboratory experiments using a wide variety of soil samples from 16 farms across Pennsylvania and southern New York. This research expanded our understanding of how soil microbes slowly release nitrogen, making it available to plants. We developed a new version of the tool that allows users to compare how the cost of different nitrogen fertilizer options affects the recommended application rates, allowing farmers to consider profitability in their decision-making. A key final product was a nitrogen decision support tool that assists farmers in choosing the optimal type and amount of fertilizer for their fields, maximizing profitability for farmers and improving environmental quality (Arrington et al. 2024 in products). We worked with farmers to test the tool on their fields to make sure it is easy to use and helpful in making fertilizer decisions.Specific accomplishments for each objective are as follows: Objective 1. Agronomic validation.Cover crops were planted at both the research station (all years) and the two on-farm sites (two years). Plots were divided into six subplots, with standard nitrogen addition levels 0, 30, 60, 120, 180, and 240 pounds N per acre as Chilean nitrate. Using these data, we recalibrated the equations underlying the tool with sites covering a broader range of soil textures, tripling the number of observations used to calibrate the original equations. Overall, the new model structure resulted in better correspondence between predicted and measured unfertilized corn yield. Generally, the newmodel structure resulted in lower predicted yields compared to the original model structure. The lower predicted yields were tied to higher model-calculated values for humification efficiency, a parameter indicating the degree to which soil microbes retain nitrogen in their biomass. We found the best new model included: 1) measured soil C:N instead of an assumed value of 10, 2) both sand and clay content, and 3) a precipitation adjustment factor. Using the original model dataset to validate the new model, we found good agreement between measured and predicted unfertilized corn yield. The new model can be applied to sites with a wide range of soil textures and is calibrated to average precipitation in the mid-Atlantic region. Objective 2 Biogeochemical Validation. This objective sought to examine whether some of the parameters we used in the model that underpins our decision support tool varied meaningfully across farms and soil types. We collected soil samples from 16 locations (commercial farms and the research station) across Pennsylvania and southern New York. We measured laboratory N mineralization rates, microbial biomass carbon and nitrogen, microbial community

structure (via phospholipid fatty acid analysis), microbial carbon use efficiency, carbon nitrogen concentration, and soil texture. Carbon use efficiency is a proxy for humification efficiency (ε) (a key parameter in our N tool model) that we measure as the quantity of 18O incorporated into microbial DNA technique) across fields. We found that microbial C:N was lower and more variable than assumed in the model, ranging from 4 to 10 in the soils we collected. Microbial C:N was also strongly negatively correlated with the quantity of nitrogen mineralized over a 12-week laboratory incubation. Similarly, soil C:N was variable, ranging from 7 to 11, and negatively correlated with nitrogen mineralization To isolate the effect of soil texture of on ε, we carried out a manipulative texture experiment. We developed the technique to sieve sand from a fine-textured soil sampled from a single plot at the research station and then incrementally add the sieved sand to the original fine-textured soil to create a manipulated gradient of soil textures. We used 13C-glucose tracing methods to track the fate of added carbon through the pools of microbial biomass and soil organic matter and can then compare the 13C accumulated in these pools to the 13C lost as CO2 . Soils from the manipulated soil texture gradient displayed more consistent microbial respiration patterns than the field soils. We also found evidence for priming effects in the soils with the added glucose and alanine tracer, where microbes in soils with the added tracer mineralized additional native soil organic matter compared to soils with no added tracer. Additionally, priming effects increased with increasing sand content, indicating that there may be more scavenging and recycling of soil organic matter in sandy soils. These results were presented at the Soil Science Society of America meeting, garnering an award for student presenter Madeline Luthard. Objective 3 Outreach.Our primary outreach goal was to share the N decision support tool with farmers and solicit their feedback regarding the visualization, inputs, and outputs of the web dashboard interface. In each year of the project we shared our N decision support tool with our farmer advisory board and incorporated their suggestions into the tool development. We led and participated in many outreach events during the project (see \"other products), here we highlight some examples from throughout the project. We developed a webinar as part of Penn State Extension\'s \"Making Cover Crops Pay\" series. We showed how different cover crops affect the corn yield response to nitrogen additions (based on data from the research station and on-farm sites) and demonstrated the nitrogen decision support tool. We gave two presentations at Penn State\'s Ag Progress days. We shared several scenarios with the audience to compare how cover crops and soil organic matter affect the tool\'s nitrogen fertilizer recommendations. We gave a presentation Lancaster-Lebanon Watershed Forum and Science Symposium in Elizabethtown, PA. Here we focused on the effectiveness of cover crops to reduce nitrogen leaching based on nine years of data at the Penn State research station. We presented at a farmer meetings organized by the Snyder County Conservation District and by Penn State Extension\'s Organic Learning Circles group. We updated our web-based N tool (https://extension.psu.edu/nitrogen-recommendations-for-corn) with the recalibrated equations developed in Objective 1. The new version of the website allows users to consider the economics of applying nitrogen fertilizer by entering the fertilizer cost and an expected price for corn. A dynamic graph illustrates how changes in the inputs affect the predicted fertilizer response curve and the N fertilizer recommendation.We added a cover crop C:N lookup table to the N decision support tool. We combined our research station dataset with a similar dataset from commercial farms across Pennsylvania, resulting in a total of approximately 1200 samples collected from 2011-2023. The table provides averages and ranges of C:N ratios for a varietyof cover crop species and mixtures. Also, it provides users with guidance on adjusting the average C:N in the table based on manure applications before or during the cover crop growth period. Publications Type: Journal Articles Status: Published Year Published: 2024 Citation: Arrington, K. E., Ord��ez, R. A., Rivera-Ocasio, Z., Luthard, M., Tierney, S., Spargo, J., Finney, D., Kaye, J. P., & White, C.M. (2024). Improving a nitrogen mineralization model for predicting unfertilized corn yield. Soil Science Society of America Journal,88(3), 905-920. https://doi.org/10.1002/saj2.20665 Type: Theses/Dissertations Status: Published Year Published: 2023 Citation: Mickles, Austin, \"Audience Driven Scientific Communication in Agricultural Research\" (2023). Environment and Sustainability Honors Papers. 13. https://digitalcommons.ursinus.edu/environment_hon/13. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Rivera-Ocasio, Z., Montiel-Fernandez, L., King, W., Heer, P., Kaye, J. P., White, C. (2024). \"Estimating Microbial Carbon Use Efficiency as the Pivot Point for a Nitrogen Decision Support Tool,\" Soil Science Society of America Summer Conference, San Juan, Puerto Rico. Progress 09/01/22 to 08/31/23 Outputs Target Audience:Through many events over the past year, we reached our primary target audience of farmers and agricultural professionals in the mid-Atlantic region, who are potential users of the nitrogen decision support tool for corn (N tool). In February, we met with our farmer advisory board (farmers growing organic corn across Pennsylvania) to share experiences with the 2022 growing season, discuss the N tool development and plan outreach events. We introduced the N tool to both organic and conventional farmers at several outreach events, including a farmer meeting organized by the Snyder County Conservation District, a soil health field day hosted by Stroud Water Research Center and three workshops at Penn State\'s Ag Progress Days. We also had the opportunity to expand the geographic reach of our work through two webinars that introduced the N tool as a part of a discussion of building soil health. We had several opportunities to share our work with other researchers and the Penn State community. In November 2022, manyof our teammembers attended the ASA-CSSA-SSSA Annual Meeting in Baltimore. We shared our research findings supporting the N

tool with scientists and agricultural professionals though several poster and oral presentations. In January, we presented at the Penn State Plant Science Department Seminar, which included our team\'s development of the N tool along with the work of our collaborators who conduct other experiments at our Penn State research station. In April, three of our students presented their independent research related to this project at the Penn State Undergraduate Exhibition. Over the past year, this project has provided many opportunities to reach our secondary target audience of students interested in organic agriculture. Ten undergraduates/recent graduates including seven at Penn State and three at Ursinus participated in a combination of field sampling, laboratory analyses, and presenting research results. Students participated in fieldwork at the Penn State research station and other farms where soil samples were collected for the laboratory incubations. We also hosted a workshop for 22 high-school students as part of the Pennsylvania School for Excellence in the Agricultural Sciences. Students visited the Penn State research station to learn about cover crops and participated in a hands-on experience processing soil samples in our campus laboratories. Changes/Problems:The winter extension meeting scheduled for December 2022 was cancelled due to the weather. We adapted our planned workshop to a shorter format, which was given each of the three days of Penn State\'s Ag Progress Days in August 2023. What opportunities for training and professional development has the project provided?The project has provided many opportunities for training and professional development. Ten undergraduate students participated in agricultural research through assisting with field and laboratory work for this project. Four undergraduates led independent research related to the N tool development, which provided opportunities to communicate with farmers and present posters at a scientific conference and an exhibition at Penn State. At Penn State, undergraduates participated in the development of a cover crop lookup table, measuring soil respiration rates across a soil texture gradient, and estimating carbon credits at the Penn State research station. At Ursinus, an undergraduate student wrote an honors thesis on communication strategies in agricultural science. Two graduate students, two laboratory technicians and a postdoctoral scholar helped to train and mentor the undergraduate students in their research experiences. We included these students in lab group meetings, which provided opportunities to listen to presentations by graduate students, discuss scientific journal articles, review draft manuscripts/presentations, and view preliminary datasets that they had helped to collect. The two graduate students (PhD candidates) are each leading a component of this project as part of their dissertation research. Most of our project team members have had several opportunities to present data collected as part of this project and to participate in outreach events. How have the results been disseminated to communities of interest?We have continued to work with the farmers on our advisory board to guide the development of the N tool and the outreach component of this project. This partnership includes sharing data and farmer experiences to improve the tool and identify outreach opportunities. In February 2023, we met virtually with this team to share research updates including 2022 corn yields at the on-farm sites and the research station, recalibrating the N tool model and the development of a cover crop look-up table. Over the past year, we have expanded our outreach to a broader group of farmers through a variety of in-person and virtual extension events. These events included a presentation describing the soil and cover crop data that farmers would need to use the N tool and how to obtain that information. Some of our extension events have included hands-on activities, which allowed participants to try the web-based N tool on a laptop and estimate the N content of cover crops using a handheld Greenseeker sensor (workshops at Penn State\'s Ag Progress Days and Penn State Extension\'s Agronomic Diagnostic Clinic). Farmers attending the Organic Grains Field Day visited the Penn State research station site observed visual differences of corn grown following different cover crops, reflecting their differing N contributions. Our outreach events were located at several locations across Pennsylvania as well as an online. This year, we had opportunities to share our results with other researchers through presentations at the ASA-CSA-SSSA meetings (November 2022), the Penn State Plant Science seminar (January 2023) and the Penn State Undergraduate Exhibition (April 2023). These events allowed us to present our testing and recalibration of the biogeochemical equations underlying the N tool. Members of our project team have given 20 presentations in which the N decision support tool was introduced to agricultural professionals, researchers, students, and others. These included seven oral or poster presentations at an international conference, three posters presented at a Penn State Undergraduate Exhibition, one presentation at the Penn State Plant Science seminar, two webinars and seven extension events. A complete list of events is provided in the Other Products/Outputs section. What do you plan to do during the next reporting period to accomplish the goals?Objective 1: We will submit a manuscript to the Soil Science Society of America Journal documenting the recalibration of the N tool model. We will evaluate the updated model by comparing the unfertilized corn yield predicted by the model to observed yields in the 2022 season (at the on-farm sites and the research station). Objective 2: We will complete the analysis of εas part of the biogeochemical validation process. This will include preparation of microbial biomass 13C samples (freeze drying soil extracts and encapsulating them into small tin capsules) and sending them to Cornell Stable Isotope Laboratory for isotopic analysis (early 2024). When microbial biomass 13C and soil organic matter 13C results are obtained, they will be used, along with 13C-CO2 data, to calculate ε. From there, we will determine whether there is a relationship between soil texture and ε, leveraging results from both the inherent soil texture gradient and manipulated soil texture gradient employed in our laboratory incubation. Data analysis will be completed in summer 2023 and preparation of a

publication will follow. All data from laboratory incubations conducted at Ursinus have been collected, so activities in the coming year will focus on data analysis and preparation of a publication. We will continue our analysis to identify predictors of nitrogen mineralization in the controlled laboratory incubation and use this information to further refine the N tool model. Isotope data required to quantify CUE have been received, which will allow us to proceed with the analysis of these data. We will assess temporal patterns in CUE values and determine if CUE values vary between low and high quality cover crop residues. We will also compare measured CUE values to ε values predicted by the N tool and identify soil and/or cover crop properties that may be incorporated into the model to improve estimation of ε. Objective 3: We will expand the look-up table of the spring cover crop C:N ratios by combing our research station data with the dataset used to recalibrate the N tool model. This will ensure the table includes a wide variety of cover crops grown in fields with a range of soil textures and organic matter contents. The spring cover crop C:N look-up table will be added to the web-based version of the N tool, allowing users to estimate this required input. We will complete partial budget analyses for recent years at our research station. This will provide long-term average data on the yield revenue of corn following a variety of cover crops, adjusting for the cost of seeds and planting. In addition, we will use the N addition trials at the research station in 2021 and 2022 to consider the costs of the N fertilizer compared to the revenues from yields at each N addition level. We will meet with our advisory board in winter 2024 to share research results and the updated N tool. We will continue to participate in other extension events to introduce the N tool to agricultural professionals across the mid-Atlantic region. Impacts What was accomplished under these goals? Objective 1: Agronomic validation We recalibrated the model underlying the N decision support tool using a new dataset, which included the experiments in the 2021 on-farm trials. Compared to the dataset used to calibrate the original model, the new dataset included a broader range of soil textures, a more diverse set of cover crops, and a wider range of growing season precipitation. We found the best new model included: 1) measured soil C:N instead of an assumed value of 10, 2) both sand and clay content, and 3) a precipitation adjustment factor. Using the original model dataset to validate the new model, we found good agreement between measured and predicted unfertilized corn yield. The new model can be applied to sites with a wide range of soil textures and is calibrated to average precipitation in the mid-Atlantic region. We completed a second field season with the corn harvest at the on-farm sites and research station in October/November 2022. Unfertilized corn yield was consistent for both years at one of the on-farm sites, while the 2022 yields were lower than 2021 at the other on-farm site and the research station. The yield response to the N additions varied by site and previous cover crop, providing a wide range of scenarios for testing the recalibrated N tool model. Soil samples from the second year were taken to analyze the microbial carbon use efficiency and next-generation sequencing. The quantification ofthecover crop\'s litter decomposition and N-mineralization within the nitrogen fertilizer rate treatments acrosson-farms were conducted with the buriedlitterbagtechnique. Objective 2: Biogeochemical validation At Penn State, we continued our experiment to isolate the effect of soil texture on humification efficiency (ε) by processing soil samples and analyzing results from a 3-month incubation completed in May 2022. Samples to be analyzed for soil organic matter 13C were dried, ground, acidified to remove carbonates, and then encapsulated and sent to Cornell Stable Isotope Laboratory (completed August 2023). We analyzed the data for the 13C-CO2 gas samples from the incubation study and found that the soils from the manipulated soil texture gradient displayed more consistent microbial respiration patterns than the field soils, which validates this approach as a method to isolate the relationship between soil texture and ε. We also found evidence for priming effects in the soils with the added glucose and alanine tracer, where microbes in soils with the added tracer mineralized additional native soil organic matter compared to soils with no added tracer. Additionally, priming effects increased with increasing sand content, indicating that there may be more scavenging and recycling of soil organic matter in sandy soils. We are assessing variation in assumed and calibrated parameters of the model through laboratory incubations at Ursinus College using soil samples collected from commercial organic farms and the Penn State research station. This year, we completed laboratory incubations of soil samples from 20 fields on seven commercial farms and the research station collected in spring 2022. These samples underwent the same incubation protocols used in 2021 to determine nitrogen mineralization parameters. Soil physical, chemical, and biological properties were also measured on all soils prior to incubation. Data from the incubations conducted in 2021 and 2022 (a total of 36 unique farm fields) are currently being analyzed to assess variation in microbial C:N, soil organic matter C:N, and microbial carbon use efficiency (CUE, as measured by the 18O DNA tracer technique) across fields. We are also using these data to identify relationships among soil physical properties, soil biological properties, and nitrogen mineralization dynamics. We have found that microbial C:N was lower and more variable than assumed in the model, ranging from 4 to 10 in the soils we collected. Microbial C:N was also strongly negatively correlated with the quantity of nitrogen mineralized over a 12-week laboratory incubation. Similarly, soil C:N was variable, ranging from 7 to 11, and negatively correlated with nitrogen mineralization. To elucidate the relationship between microbial CUE and residue C:N, we conducted a laboratory incubation on a subset of soils collected in spring 2022. This incubation was carried out in parallel with the primary incubation study and under the same conditions but included measurement of microbial CUE at three time points during the incubation. Objective 3: Outreach We updated our web-based N tool (https://extension.psu.edu/nitrogen-recommendations-for-corn) with the

recalibrated equations developed in Objective 1. The new version of the website allows users to consider the economics of applying nitrogen fertilizer by entering the fertilizer cost and an expected price for corn. A dynamic graph illustrates how changes in the inputs affect the predicted fertilizer response curve and the N fertilizer recommendation. We met with our advisory board (virtually) in February to share research updates and plan for future events. We participated in several other outreach events during the second year of the project, including a farmer meeting organized by the Snyder County Conservation District (February), Penn State Extension\'s Organic Learning Circles (March) and Agronomic Diagnostic Clinic (July), and Penn State\'s Ag Progress Days (August). The summer extension workshops included hands-on activities such as using a Greenseeker NDVI sensor to estimate cover crop nitrogen content, hand soil texturing and the opportunity to try the web-based N tool on a laptop. The new calibration of the N tool (from Objective 1) was used to support four on-farm demonstration trials in Lancaster County, PA in 2023. Soil and cover crop data needed to calculate the N fertilizer recommendation were collected at each site. Six rates of N fertilizer were applied at sidedressing. The N tool accurately predicted the N fertilizer requirement at all four sites. Results from these demonstration trials were shared at field days and grower meetings throughout the summer of 2023 and will continue to be shared in coming months and years. Three undergraduate research projects completed this year will lay the foundation for future outreach products to support the N tool. One student used data from our research station to estimate the carbon credits that could be earned by planting cover crops and increasing soil organic matter levels. The net revenue that could be earned through two different carbon credit programs was adjusted for the costs of cover crop seeds and planting. This type of analysis can be used in outreach events/materials to illustrate the economic implications of growing cover crops, both in the short and long term. Another student project focused on the development of a cover crop look-up table to allow farmers to estimate the C:N ratio of winter-hardy cover crops instead of collecting plant samples and sending them to a laboratory for analysis. The analysis of nine years of data at the Penn State research station indicated that the spring C:N ratio of legume cover crops is less variable than non-legumes and that growing degree days (an index of cover crop maturity) can explain some of the variability in C:N of non-legumes and mixtures. A third student designed a hands-on activity demonstrating how we conduct laboratory incubation and measure soil microbial respiration using a LI-COR gas analyzer; this activity is intended for use at future farmer meetings. She also developed two fact sheets based on findings from our laboratory incubations and a template to report measured soil properties back to farmers who provided soil for incubation studies at Ursinus. Publications Type: Other Status: Published Year Published: 2023 Citation: White, C., Spargo, J. T., & Arrington, K., et al. (2023). Soil organic matter and cover crop-based nitrogen recommendations for corn. https://extension.psu.edu/soil-organic-matter-and-cover-crop-based-nitrogen-recommendations-for-corn. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: Through several events over the past year, we shared the nitrogen (N) decision support tool with a diverse group of agricultural professionals in Pennsylvania. In March we held our annual meeting (virtually) with the farmers on our advisory board, who all grow organic corn, but are distributed geographically across Pennsylvania. We reached a broader group of Pennsylvania farmers/ agricultural professionals with several events, including a webinar in February (part of the Penn State Extension Series, \"Making Cover Crops Pay\") and two presentations at Penn State's Ag Progress Days in August. We extended our outreach beyond the agricultural community with a presentation at the Lancaster-Lebanon Watershed Forum and Science Symposium in Elizabethtown, PA (November 2021). The event brought together scientific researchers with watershed practitioners, including local government and community organizations. Our secondary target audience includes students with an interest in a career in organic agriculture. During the second year of the project, five undergraduate students at Penn State and three students at Ursinus either received academic credit or hourly wages for contributing to the research component of this project, including collecting soil and plant samples in the field and processing them for laboratory analyses. Students participated in fieldwork at the Penn State Research Station, the two on-farm research sites and other farms where soil samples were collected for the laboratory incubations. In addition to the group of students assisting with research, a broader student audience was reached through two guest lectures at Penn State. In October 2021, we gave a tour of the cover crops at the Penn State Research Station to students in an introductory agronomy course (Principles of Crop Management). Students were given an overview of how different cover crops affect soil nitrogen levels and a demonstration of using an handheld NDVI (Normalized Difference Vegetation Index) sensor to estimate the nitrogen content of cover crops. In March 2022, we presented a guest lecture to a group of upper-level undergraduates (Emerging Issues in Plant Sciences) about the nitrogen contributions of soil organic matter and cover crops, including a demonstration of the web-based nitrogen decision support tool. Changes/Problems: We have experienced delays in stable isotope analysis necessary for determination of microbial carbon use efficiency. The external labs we use to conduct these analyses experienced closures during the pandemic that have led to significant backlogs and extended turn around times. However, we are on track to send these samples in this fall. We postponed our plans for a spring or summer field day due challenges coordinating a time that project team members and farmers would be available to attend an in-person event. However, we did participate in other outreach activities, such as Penn State's Ag Progress Days. We have scheduled an in-person outreach event for December 2022. What

opportunities for training and professional development has the project provided? The project has provided many opportunities for training and professional development. Eight undergraduate students participated in agricultural research through assisting with field and laboratory work for this project. Two graduate students, two laboratory technicians and a postdoctoral scholar helped to train and mentor the undergraduate students in their research experiences. We included these students in lab group meetings, which provided opportunities to listen to presentations by graduate students, discuss scientific journal articles, review draft manuscripts/presentations and view preliminary datasets that they had helped to collect. Two graduate students (PhD candidates) are each leading a component of this project as part of their dissertation research. Several project team members have had opportunities to attend conferences to present data collected as part of this project and learn about related research and outreach. How have the results been disseminated to communities of interest? We have continued to work with the farmers on our advisory board to guide the development of the N tool and the outreach component of this project. This partnership includes sharing data and farmer experiences to improve the tool and identify outreach opportunities. In March 2022, we met virtually with this team to share research updates and plan for farm visits and future outreach events. We shared the corn yield response to nitrogen additions at the research and on-farm sites and one farmer shared his experience with participating in the on-farm research. We presented results of nitrogen mineralized during laboratory incubations of soil samples collected from ten farms across Pennsylvania, including fields from some of the farmers in this group. We shared results of Greenseeker NDVI (Normalized Difference Vegetation Index) readings taken weekly at the research station in Spring 2021. This research was initiated in response to a question at the 2021 advisory board meeting: would readings taken early in the spring provide a reasonable estimate of the nitrogen content of cover crops at termination? Farmers were interested in this question because taking Greenseeker readings early in the spring would allow them more time to plan for manure and fertilizer applications. Also, we discussed interest among the farmers in having a member of our team visit their farm to collect soil samples to analyze for texture and organic matter (inputs to the N tool) and demonstrate taking NDVI readings with the Greenseeker. We followed up with two farms visits in the spring/summer 2022. Finally, we discussed plans for future outreach events to share the N tool with broader audiences. Farmers recommended seeking out opportunities to participate in existing outreach events in addition to planning our own field day. Members of our project team have given twelve presentations in which the N decision support tool was introduced to agricultural professionals, researchers, students and others. These presentations were given at two webinars, four conferences, four extension events and two guest lectures. A complete list of events is provided in the Other Products/Outputs section. What do you plan to do during the next reporting period to accomplish the goals? Objective 1: Agronomic validation: The second year of data collection will be completed with the corn harvest in October/November 2022, when we will measure yield and the N content of the corn ears for the six N levels of each plot at the research station and on-farm sites. These data combined with the plot-specific cover crop biomass nitrogen and soil properties will be used to test the recalibrated model's ability to predict unfertilized corn yield using an independent dataset. In addition, the corn yield data for the N addition subplots will allow us to assess the accuracy of the N tool fertilizer recommendations. Objective 2: Biogeochemical validation We will complete the processing of the soil samples from the eleven farms and the research station to determine the C:N ratio of these soils and their microbial biomass. Our expected outcome from this analysis is that C:N ratio of soil and microbial are similar (\~10), validating this assumption in the biogeochemical equations underlying the N decision support tool. We will complete the estimations of microbial carbon use efficiency using the 18O tracer technique to determine the humification efficiency (ε) for the soil samples collected from the eleven farms and the research station. These results will allow us to evaluate the relationship between soil texture and humification efficiency in the biogeochemical equations. We will complete the soil and soil extract analyses for the manipulated texture experiment. This will complete our dataset and from there we can begin data analysis to assess trends in Carbon Use Efficiency and humification efficiency as a function of soil texture. We will evaluate the recalibrated model';s calculated values for humification efficiency by comparing them to measured values the laboratory incubation studies and also from a litter bag decomposition study in the field (at the research station). Objective 3: Outreach We have scheduled a winter extension meeting for December 16, 2022 in New Columbia, PA. This will be a half-day outreach event with a focus on the nitrogen decision support tool. We will provide a short introduction to the concepts of the fertility of soil organic matter and cover crops, an overview of the field and laboratory research components of the project and a demonstration of using the web-based version of the tool. The remainder of the time will be used for hands-on activities, including using the Web soil survey to estimate soil texture, hand texturing soil samples, taking Greenseeker NDVI readings to estimate the nitrogen content of cover crops, and testing scenarios using the web-based N tool. The event will also allow time for questions about farmers sharing experiences with planting cover crops and nitrogen management for corn. We will complete the cover crop look-up table, which will allow farmers to use the tool without having to collect cover crop samples to determine their spring C:N ratio. Also, as an alternative to collecting NDVI readings in the field, the table will provide estimates of the nitrogen content of cover crops in the spring. The estimates in the look-up table will be developed from a dataset of cover crop samples collected from sites across Pennsylvania as part of over a decade of research at Penn State. The

look-up table will include a wide variety of cover crop species and mixtures, with subgroups for plant maturity and legume percentage for mixtures. **Impacts** What was accomplished under these goals? We are working to refine the nitrogen (N) decision support tool in several ways, including expanding the range of sites for which it is valid, testing the underlying assumptions and providing ways to estimate the inputs required to run the tool. The original equations used to calculate fertilizer recommendations were developed for fine to medium-textured soils. We have expanded our input dataset to include sites with coarser-textured soils and recalculated the equations. We are testing the new equations with both field and laboratory experiments to make sure that the underlying assumptions are valid and that their recommendations are appropriate for a broad range of sites. In addition, we are developing outreach materials to facilitate the use of the tool. One example is the cover crop look-up table, which will allow farmers to estimate the cover crop information needed to run the tool without having to collect samples or take readings in the field. Objective 1: Agronomic Validation We completed the first year of the agronomic validation with the corn harvests at the on-farm sites and research station in October/November 2021. At both the on-farm sites and the research station, 2021 was a high-yield year for corn. However, the N tool predictions for unfertilized corn yield did not correspond well with measured yields. In part, this was due to the fact that some of the plots at the research station and the fields at one of the on-farm sites had coarser-textured soils than the sites used to develop the equations for predicting unfertilized corn yield. We recalibrated the equations underlying the tool with sites covering a broader range of soil textures. The expanded calibration dataset included data collected from previous research projects along with the on-farm research sites, resulting in nearly triple the number of observations used to calibrate the original equations. Overall, the new model structure resulted in better correspondence between predicted and measured unfertilized corn yield. We used the 2021 research station data as an independent test dataset for the recalibrated equations. Generally, the new model structure resulted in lower predicted yields compared to the original model structure. The lower predicted yields were tied to higher model-calculated values for humification efficiency, a parameter indicating the degree to which soil microbes retain nitrogen in their biomass. We began the second year of the agronomic validation with planting cover crops (August 2021) at different fields for the on-farm sites and a different entry at the research station. We used the same methods as year 1, including collecting cover crop biomass samples and measurements of NDVI (Normalized Difference Vegetation Index) in fall and spring. Four to five weeks after corn planting at the research station and the on-farm sites, plots were divided into six subplots for nitrogen additions. We used the same methods as year 1 for the N additions, except for replacing the highest rate (240 pounds per acre) with a lower rate (90 pounds per acre) at the research station. This change was based on the limited yield response to the higher nitrogen levels for many research station plots in year 1. Objective 2: Biogeochemical Validation We completed laboratory incubations of soil samples from sixteen agricultural fields collected from four different commercial farms and the Penn State research station in spring 2021. In addition to estimating nitrogen mineralization from five cover crop residues, we also determined initial microbial biomass carbon and nitrogen, microbial community structure (via phospholipid fatty acid analysis), microbial carbon use efficiency, carbon nitrogen concentration, and soil texture. Carbon use efficiency is a proxy for humification efficiency (ε) that we measure as the quantity of 18O incorporated into microbial DNA. In spring 2022, we collected additional soil samples from 20 fields on seven commercial farms and the research station. These samples have undergone the same incubation protocols used in 2021 to determine nitrogen mineralization parameters and have been processed to determine initial microbial and soil properties. Data from 2021 and 2022 will be analyzed to assess correlations between nitrogen mineralization and soil properties. These analyses will inform modifications to the biogeochemical equations used in the N decision support tool. In addition, microbial carbon use efficiency data will be used to determine whether soil texture is a predictor of humification efficiency (ε). We continued with our manipulative texture experiment by completing a 3-month laboratory incubation to evaluate the influence of soil texture on Carbon Use Efficiency and humification efficiency. Soils from the research station represent a range of \~17-47% sand, so we used these soils for the incubation. Additionally, we constructed soils to represent a wider texture gradient, \~17-59% sand, which expands our ability to calibrate the tool to be effective for sites with greater sand content than what is present at our PSU field site. We used13C-glucose tracing methods to track the fate of added carbon through the pools of microbial biomass and soil organic matter and can then compare the13C accumulated in these pools to the13C lost as CO2. As a result of the incubation, we collected over 250 gas samples, which were analyzed for13C-CO2. We also collected over 250 soil samples, which will be analyzed for the13C content of soil organic matter, and over 500 soil extracts, which will be analyzed for the13C content of microbial biomass. Objective 3: Outreach We met with our advisory board (virtually) in March to share research updates and plan for future events. Research updates included the role of soil texture in nitrogen mineralization (from laboratory incubations), how Greenseeker NDVI readings change over time and yield response to nitrogen at the on-farm research sites. In addition, one farmer shared his experiences with participating in the on-farm trials. We discussed content/timing for an in-person outreach event. We participated in several other outreach events during the second year of the project. In February, we developed a webinar as part of Penn State Extension's \"Making Cover Crops Pay\" series. Content focused on the effects of cover crops at three time scales: reducing nitrogen leaching while they are growing (fall through spring), influencing nitrogen

mineralization during the corn growing season and building long-term soil fertility by increasing organic matter. Also, we showed how different cover crops affect the corn yield response to nitrogen additions (based on data from the research station and on-farm sites) and demonstrated the nitrogen decision support tool. In August, we gave two presentations at Penn State's Ag Progress days. We shared several scenarios with the audience to compare how cover crops and soil organic matter affect the tool's nitrogen fertilizer recommendations. Also, we showed participants how to use the Greenseeker NDVI sensor on the cover crop demonstration plots. In November 2021, we gave a presentation Lancaster-Lebanon Watershed Forum and Science Symposium in Elizabethtown, PA. Here we focused on the effectiveness of cover crops to reduce nitrogen leaching based on nine years of data at the Penn State research station. We began working on a new outreach product to complement the N tool: the cover crop look-up table. The table will provide estimates of the carbon to nitrogen ratio (C:N) of different cover crop species and mixtures, which will allow farmers to use the tool without having to collect cover crops samples for laboratory analysis. We created a preliminary version of the look-up table by summarizing the cover crop biomass data collected at the Penn State research station since 2012. **Publications** - Type: Journal Articles Status: Published Year Published: 2022 Citation: Zhang, Z, J.P. Kaye, B.A. Bradley, J.P. Amsili, V. Suseela. 2022. Cover crop functional types differentially alter the content and composition of soil organic carbon in particulate and mineral-associated fractions. Global Change Biology 28: 5831-5848. DOI: 10.1111/gcb.16296

PROGRESS

2020/09 TO 2021/08 Target Audience:The goal of our project is to develop a nitrogen (N) decision support tool suitable for calculating the N fertilizer requirement for any corn field in Pennsylvania. Accordingly, Pennsylvania farmers growing corn are our primary target audience. In addition, consultants, extension educators and any agricultural professionals who assist with making N fertilizer decisions would be included among those we seek to reach through our outreach activities. Through presentations/posters at a number of events/webinars over the past year, we introduced the N decision support tool to a diverse group of agriculture professionals in Pennsylvania and other states as well as members of environmental/conservation NGOs and regulatory agencies. To help us test and improve the N tool, we held a meeting (virtually) with our advisory board to vet ideas regarding the visualization, inputs, and outputs of the web dashboard interface. We have worked closely with many of the farmers in this group through previous research and extension activities and they have indicated a strong interest in continuing to work with us to develop our N decision support tool. These farmers are distributed geographically across Pennsylvania and southern New York. Several are involved with farmer network groups (including the Central Susquehanna Valley Organic Crop Producers Network and PASA Sustainable Agriculture) and a few have offered to host educational events for this project at their farms. Thus, we are optimistic that the strong interest of our advisory board in the N decision support tool along with their connections with other farmers will help us to expand our target audience in the second and third year of the project. Our secondary target audience includes students with an interest in a career in organic agriculture. During the first year of the project, three undergraduate students at Penn State and two students at Ursinus either received academic credit or hourly wages for contributing to the research component of this project through assisting with activities in the laboratory and the field, including the research station and commercial farms. Penn State students were given a demonstration of the web-based N tool (similar to the one at our advisory board meeting) to show how farmers could use the tool to account for the N contributions of soil organic matter and decomposing cover crops. Changes/Problems:Our outreach approach was impacted by safety concerns about in-person events during the pandemic. Therefore, we decided not hold a field day as planned for the first year of the project. Still, we were able to hold a meeting over Zoom with our advisory board members and participate in several conferences virtually. We plan to have a field day in spring 2022. What opportunities for training and professional development has the project provided?The project provided opportunities for five undergraduate students to participate in agricultural research through assisting with field and laboratory work. We included undergraduate students in lab group meetings which provided opportunities to listen to presentations by graduate students, discuss scientific journal articles and ask questions about attending graduate school. The Agroecology Lab at Ursinus College, guided by Dr. Denise Finney provided a workshop for two graduate students to learn how to measure microbial carbon use efficiency using the oxygen-based stable isotope technique. The workshop applied the method of learning by doing and covering the process from sample management, calculating the amounts of labeled water additions, running the incubations, doing microbial carbon biomass and microbial respiration. Several project team members attended scientific conferences where the N decision support tool project was represented, including the PASA 2021 Virtual Sustainable Agriculture Conference, where we contributed a presentation and the Northeast Cover Crops Council 2021 Virtual Conference, where we contributed a poster. How have the results been disseminated to communities of interest?In March 2021, we met with our advisory board (via Zoom) and shared two versions of our N decision support tool: 1) the current version on the Penn State Extension website (https://extension.psu.edu/graphical-analysis-tool) and the pilot \"Economic Optimum\"

version, which considers how the cost of nitrogen fertilizer can reduce the optimum application rate. Farmers at the meeting tested both versions of the tool using site-specific soil and cover crop information from their farms (collected through previous on-farm research projects). There was a strong interest in the web-based N decision support tool, especially the Economic Optimum version. Advisory board members posed questions and offered suggestions and we will use this feedback to guide the development of future versions of the tool. Members of our project team have presented 9 talks or posters at outreach events in which the N decision support tool was introduced to agricultural professionals in Pennsylvania and other states. We contributed to the PASA 2021 Virtual Sustainable Agriculture Conference with a recorded presentation about the principles that regulate N availability from cover crops and soil organic matter along with a demonstration of our web-based N decision support tool. This annual event typically brings together over 2,000 growers, buyers, distributors and consumers. A complete list of events is provided in the Other Products/Outputs section. What do you plan to do during the next reporting period to accomplish the goals?Objective 1: Agronomic validation: The first year of data collection will be completed with the corn harvest in October 2021, when we will measure yield and the N content of the corn ears for the six standard N levels of each plot at the research station and on-farm sites. These data combined with the plot-specific cover crop biomass nitrogen and soil properties will be used to conduct our first test of the model\'s ability to predict unfertilized corn yield using an independent dataset. In addition, the corn yield data for the N addition subplots will allow us to assess the accuracy of the N tool fertilizer recommendations. This August we initiated our second year of the agronomic validation with the planting of cover crops in a different entry of the research station and different fields at the on-farm sites. We will repeat the methods from the first year of the project, including collecting NDVI readings, sampling and analyzing cover crop biomass, planting corn following cover crop termination and applying Chilean nitrate at six standard N addition levels in the corn plots. Objective 2: Biogeochemical validation We will complete the processing of the soil samples from the ten farms and the research station to determine the C:N ratio of these soils and their microbial biomass. Our expected outcome from this analysis is that C:N ratio of soil and microbial are similar (\~10), validating this assumption in the biogeochemical equations underlying the N decision support tool. We will complete the incubations using 13C-glucose tracing to determine the humification efficiency (ε) for the soil samples collected from the ten farms and the research station. These results will allow us to evaluate the relationship between soil texture and humification efficiency in the biogeochemical equations. We will complete the incubations using 13C-glucose tracing to determine the humification efficiency (ε) for the soils in the manipulated texture gradient and the inherent texture gradient at the research station. These results will allow us to isolate the effect of texture on ε by reducing the variability in other factors among the soil samples from the commercial farms. They will create a second independent dataset to test the biogeochemical equations. Objective 3: Outreach We will use the feedback from our first advisory board meeting to incorporate more guidance for users to enter inputs to the tool and interpret the results. Links will be added next to each input to help users collect or estimate the site-specific information needed to use the tool. In addition, more information will be added to help users interpret the outputs of tool, including explanations of concepts such as yield gap, microbial carbon use efficiency and fertilizer efficiency. Limitations of the tool will be mentioned, such as the fact that we are still testing and refining the tool for use on coarser-textured soils (those with greater than 50% sand) and that fertilizer recommendations are based on average-year temperatures and precipitation in Pennsylvania. We will hold a second advisory board meeting in spring 2022 share the next version of the web-based N tool. We will work with extension educators to make sure that the farmers on our advisory board have the opportunity to use the Greenseeker NDVI sensor to estimate the nitrogen content of cover crop biomass on their fields to use as inputs to the N tool. We will work with these farmers to use the N tool for fields that will be planted in corn to compare the the N recommendations calculated by our decision support tool to the N application rates they would determine through other tools or methods. We will hold a field day in spring 2022 to test the N decision support tool with farmers beyond those on our advisory board. Field day attendees will engage in participatory activities such as assessing cover crop biomass and N content with the NDVI meter, using the decision support tool to estimate fertilizer or manure input needs, and calculating impacts of fertilizer choices on economic returns. We will continue to participate in conferences and other outreach events to introduce the N decision support tool to agricultural professionals in Pennsylvania and other states. For example, we will be presenting at the Keystone Crop and Soils Conference in October 2021. Attending this meeting will be approximately 150-200 Certified Crop Advisors, who will be earning their continuing education credits in several subjects, including nutrient management.

IMPACT

2020/09 TO 2021/08 What was accomplished under these goals? One of the challenges that farmers face is deciding which fertilizers to use and how much to apply to their fields. Nitrogen is an important plant nutrient and component of most fertilizers. Too little nitrogen stunts crop growth, but too much can cause excessive weed pressure and nitrogen losses to the environment. Excess nitrogen in drinking water can make it unsafe for human consumption and excess nitrogen in lakes and streams can be detrimental to aquatic life and human recreation.

Although most crops require supplemental nitrogen for optimum growth, some nitrogen can be supplied from the soil and decomposing plant residues, including cover crops, which some farmers grow from fall to spring. We have developed an online tool that predicts corn yield based on the amount of nitrogen that is slowly released from the soil and decomposing cover crops. Using site-specific information, the tool calculates the amount of nitrogen needed to supplement the existing soil fertility and to achieve a goal for corn yield. Through this project we are working to test our tool on corn fields across Pennsylvania with a wide variety of cover crops and soil types. We are testing the accuracy of the equations for predicting corn yield with field research at three sites: our research station in central Pennsylvania and two commercial farms in northeastern and southeastern PA. These experiments involve applying nitrogen fertilizer at six rates at each site or plot to test the accuracy of the fertilizer recommendations calculated by the tool. Also, we are performing laboratory experiments using a wide variety of soil samples collected from 11 farms across Pennsylvania and southern New York. This research will expand our understanding of how soil microbes slowly release nitrogen, making it available to plants. Finally, we are working with a small group of farmers to test the tool on their fields to make sure it is easy to use and helpful in making fertilizer decisions. We are developing a new version of the tool that allows users to compare how the cost of different nitrogen fertilizer options affects the recommended application rates, allowing farmers to consider profitability in their decision-making. Ultimately our goal is to provide a nitrogen decision support tool that assists farmers in choosing the optimal type and amount of fertilizer for their fields, maximizing profitability for farmers and improving environmental quality. Objective 1: Agronomic Validation We accomplished the proposed tasks for the first year of the agronomic validation with a few changes to the methodology. Cover crops were planted at both the research station and the two on-farm sites, but at the on-farm sites farmers selected the cover crops, rather than using the three cover crop types we had planned (grass, legume and grass/legume mix). Both farmers selected winter-hardy cover crops, so we did not sample fall biomass at the on-farm sites because this information was not needed to test the N decision support tool. At both the research station and the on-farm sites, we sampled cover crop biomass in all plots just before termination to calculate the cover crop nitrogen content and C:N ratio. Also, we took NDVI readings at all biomass sampling locations to test the equations we are using to estimate cover crop nitrogen content in the N decision support tool. At the research station and the on-farm sites, plots were divided into six subplots, with standard nitrogen addition levels 0, 30, 60, 120, 180, and 240 pounds N per acre. We used the six standard N rates (rather than the four variable rates based on N tool recommendations indicated in the proposal) because the two additional N levels will allow us to better determine the shape of the yield response curve for each site and cover crop type. Also, the six standard levels will allow us to compare the response curves of different sites and cover crop types with a consistent methodology. Finally, exposing the corn to a wide range of N availability will identify cases in which the N tool fertilizer recommendation were incorrect, allowing us to recalibrate the model if needed. At both the research station and the on-farm sites, we used Chilean nitrate for the N additions (rather than feather meal) because it has a more defined availability (100%) and is easier to handle for research purposes. Objective 2: Biogeochemical Validation In spring 2021, we collected soil samples from 11 locations (ten commercial farms and the research station) for the biogeochemical validation of the model underlying the N decision support tool. The soil samples were collected from locations across Pennsylvania and southern New York and they cover a wide range of soil textures and organic matter levels. We are processing these samples to determine the C:N ratio of both the soil and the microbial biomass. Also, we began the incubations of these soil samples using 13C-glucose tracing to determine whether variation humification efficiency (ε) across farms is correlated with soil texture. While these soil samples cover a wide range of textures, they may differ in other ways that affect ε, such as differences in soil microbial communities. To isolate the effect of soil texture of on ε, we began our manipulative texture experiment. We developed the technique to sieve sand from a fine-textured soil sampled from a single plot at the research station and then incrementally add the sieved sand to the original fine-textured soil to create a manipulated gradient of soil textures. The manipulated gradient includes the existing range of textures at the research site and a sandier soil similar the coarser-textured soils at one of the on-farm sites. We did one pilot incubation with these soils using a single type of cover crop litter (C:N\~20) to determine the appropriate moisture level to use for future incubations. Objective 3: Outreach Our primary outreach goal for the first year of the project was to share the N decision support tool with farmers and solicit their feedback regarding the visualization, inputs, and outputs of the web dashboard interface. In March 2021, we hosted a Zoom meeting with our advisory board members, where we shared two versions of our N decision support tool with this group: 1) the current version on the Penn State Extension website (https://extension.psu.edu/graphical-analysis-tool) and the pilot \"Economic Optimum\" version, which considers how the cost of nitrogen fertilizer can reduce the optimum application rate. Since we had worked with these farmers in the past, we were able to compile site-specific soil and cover crop information for each farmer to enter as inputs to the tool. The farmers who tested the N decision support tool provided valuable feedback to guide the development of future versions of the tool. They pointed out that not all farmers will have site-specific soil texture information for their fields, so it would be helpful to add a feature to help users to estimate soil texture. Our test users were very interested in using the Greenseeker NDVI sensor to estimate the nitrogen content of cover crop biomass, but they had a number of questions including where to borrow a Greenseeker

sensor and when NDVI readings could be taken. These questions will help us to incorporate more guidance into the tool. In addition, they led us to investigate how NDVI readings changed over the spring growing season for different cover crops grown at the research station, which will help us to develop new guidance for when to take NDVI readings. Finally, our advisory board members provided a number of ideas for ways to expand the scope of the tool, such as the incorporating the ability to consider how manure applications would affect other nutrients besides nitrogen and how fertilizer recommendations could be adapted for year-to-year weather variability. **PUBLICATIONS (not previously reported):** 2020/09 TO 2021/08 Type: Journal Articles Status: Published Year Published: 2020 Citation: White CM, Finney DM, Kemanian AR, Kaye JP. Modeling the contributions of nitrogen mineralization to yield of corn. Agronomy Journal. 2020;1&#65533;14. <https://doi.org/10.1002/agj2.2047>.

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Boa: Organic Confluences: Developing Open-access and Scale-agnostic Technology for Organic Farmers

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NON-TECHNICAL SUMMARY

Because organic farmers are banned from using common conventional materials such as most synthetic pesticides and fertilizers, the tools available to tackle common agricultural challenges are limited. Agricultural technology (AgTech) could provide sustainable, organic-compliant methods to overcome organic obstacles, but there is a disconnect between what has been built by AgTech innovators and the needs of organic producers because of a lack of organic-AgTech collaborations. In addition to the lack of communication between organic farmers and AgTech innovators, the diversity of organic farming operations presents the need for AgTech discussions to include issues such as accessibility of technology for small and/or low-income farms, equity around tech use and adoption, and inclusion of marginalized farming communities in the development of AgTech. This conference will address this need by hosting an event that will examine the needs of small to mid-size farming operations, foster partnerships to produce free, open-source tools for organic farmers, and explore solutions to barriers that prevent AgTech adoption. These may include monetary limitations, variation in technological literacy, and language, age, or cultural barriers. The conference will include a workshop where organic farmers are paired with AgTech programmers in a hackathon, where they will collaboratively build code, prototypes, and schematic ideas. In addition to the immediate benefits from tools developed at the hackathon, this conference will provide a lasting connection between AgTech programmers and organic farmers, as well as develop a scaffolding to improve AgTech equity and access in the organic sector.

OBJECTIVES

Our long-term goals are to equip organic farmers with tools that will 1) encourage farmers to increase the adoption of organic practices and 2) allow organic farming to be more feasible and profitable. Our overall objectives include expanding communication and collaboration between the diverse organic sector and AgTech innovators in order to develop partnerships that will explore feasible, accessible solutions to address organic farming challenges.To achieve these objectives, we will hold a conference that brings together farmers, scientists, educators, policymakers, AgTech innovators, and software programmers. This will provide an opportunity for farmers to share their needs and priorities, and for AgTech innovators to offer potential solutions. The Organic Confluences Conference will facilitate this communication and simultaneously address challenges to

AgTech access through an interactive series of panels, lightening presentations, and discussions. We will also include a hackathon that will match farmers with programmers and Agtech innovators to collaboratively build software and hardware prototype designs of actual solutions. The outcomes of this conference will culminate in a white paper and scientific publication that will offer policy recommendations to help reduce the barriers between AgTech and organic farming- particularly for smaller farmers with diverse backgrounds. Specifically, this conference aims to:Provide a venue for a diverse array of organic farmers to directly convey their needs to AgTech innovators and to learn about new technologies that are being developed. Identify tactics to enhance the accessibility and usability of expensive or specialized technology to small and low-resource organic farmers. Strategize on the design of scale-agnostic AgTech, and determine means to overcome generational, language and technological literacy-based challenges. Coordinate development and execute early stage open-source AgTech programs and prototype designs for organic agriculture through a hackathon conducted in partnership with the Gathering for Open Agricultural Technology (GOAT).Develop strategies to increase continued partnerships between AgTech and farmers.

APPROACH

The Organic Confluences Conference will bring together up to 200 participants including organic and transitioning farmers, AgTech innovators, programmers, scientists, industry members, policymakers and educators.The conference will be highly interactive and facilitated by the PD, who has extensive facilitation experience with diverse groups. Programing will take a multifaceted approach to improve communication among organic stakeholders and the AgTech sector.Day 1 will focus on matching farmer needs with AgTech opportunities. Sessions will allow organic farmers to share their needs and priorities for technological advances and include a targeted discussion on how to make technology more inclusive of farmers across cultural diversities and scales. AgTech innovators will share current opportunities and breakout discussions will allow all stakeholders to develop a framework for continued collaboration between the organic and AgTech sectors, develop an evaluation method to ensure future innovations are developed with organic ideals, and discuss how to make future AgTech accessible and relevant for all organic farmers. The day will end with the formation of multisector teams (including farmers, AgTech innovators, programmers and other organic stakeholders) who will participate in the hackathon on Day 2.Day 2 will focus on creating protypes and strategies to tackle organic challenges with technological solutions. Programmers and stakeholders will work together in teams with facilitation from mentors who will move between groups, provide guidance and feedback, and serve as early testers for the teams\' hackathon outputs. Protypes, ideas and strategies will be presented to the whole conference group, and the day will end with a summary discussion of presented topics and break-out session information to synthesize ideas for improving the organic sector\'s ability to access, influence and leverage technological advances to address agronomic needs and expand organic acreage. Progress 09/01/20 to 03/01/22 Outputs Target Audience: The target audience for this event was broad by design: we brought together farmers, researchers, ag tech professionals, extension agents, industry members, students and key policy influencers to address access and equity challenges in ag tech. Specifically, we worked with open-source software and hardware developers, organic farmers, researchers, USDA staff, extension agents, and certifiers. We also worked with think tanks that support AgTech startups and innovations, and AgTech thought leaders who were able to bring in AgTech members who have previously not interacted with organic. Researchers with specialties in open-source technology were targeted as well as sociologists that have studied how AgTech affects farmers and rural communities. We involved these broad stakeholders including farmers, industry members, researchers, extension agents, USDA staff, and regional organic farming associations from across the nation by holding listening sessions, implementing a survey, and holding one-on-one conversations to gather input on priorities and develop the conference and hackathon agenda. We focused outreach to farms and farming groups who represent marginalized communities to ensure a diversity of views in advisory and leadership positions. We also involved representatives of several agricultural technology companies who are eager to engage with organic farmers, as well as collaborating with the Gathering for Open Agricultural Technology Community. Throughout the project, we continued to engage stakeholders through an advisory committee composed of representatives from industry, farmer groups, policymakers, extension agents, scientists and food system advocates. These advisors participated throughout the development of the project, and ensured that the conference agenda and deliverables met the needs of organic stakeholders. Changes/Problems:We encountered two major challenges to completing the goals of this project. However, not only did we find solutions to both of these challenges, the solutions enabled a wider range of participants to join us. 1. COVID-19 The pandemic prevented in-person meetings from occurring, so we pivoted to a virtual meeting. This provides opportunities to engage a broader audience, and we leveraged our network to ensure that voices from around the United States were heard. While this change delayed our timeframe, it also broadened not only our speaker base, but also the participant list of who could attend. In the end, more people were able to attend because of this digital focus. 2. Disbandment of the Southern Sustainable Agriculture Working Group (SSAWG) We had originally planned to hold the conference and hackathon in tandem with the SSAWG annual meeting, but

unfortunately they closed their doors for the final time this summer. Instead, we used the platform Work Adventure to host the hackathon and partnered with multiple organizations and farmer groups who represent BIPOC farmers and groups underrepresented in tech fields to ensure broad participation and the development of an agenda and projects that would not only be impactful to farmers, but would also be minority led. What opportunities for training and professional development has the project provided?The hackathon was an excellent opportunity for training and professional development. Juliet Norton, a postdoc at Purdue, led the development of a virtual world for the hackathon in Work Adventure. Additionally, the hackathon itself trained agtech professionals in organic systems and organic practitioners in agtech development. Finally, there were several hackathon attendees who had never attended a hackathon before, and were trained in giving project pitches, working on teams, and developing software and prototypes to overcome organic challenges. How have the results been disseminated to communities of interest?When we engaged farmers in the development of dissemination tools, the top request was for recordings of the talks rather than a written report. Farmers noted that they could listen to the recordings while preparing dinner, milking cows, cleaning seeds, etc. Written reports were less useful, because they rarely had a solid chunk of time that would allow them to read technical information such as reports. In response to that feedback, and because the COVID pandemic required us to hold our events remotely, we developed recordings of all of the talks and the hackathon kick-off and final presentations. Additionally, Hackathon outputs were released as open-source projects on a Miro board, with virtual collaboration spaces available for continued work on the GOAT forum (<https://forum.goatech.org>). We also hosted a forum chat about the conference, which has garnered substantial interest from the developer sector, with posts about project concepts. We wrote an article about the conference for the Organic Report, a magazine with a distribution of over 24,000 individuals. The Organic Center also developed a web portal with a description of the conference and hackathon, updates, the agenda, and speaker bios have been posted. We also launched and maintain a social media campaign surrounding the events via The Organic Center and Organic Trade Association Facebook and Twitter accounts. The combined reach of our organizations' social media pages is followed by over 149,412 individuals for Facebook, and over 70,200 followers for Twitter. We have also leveraged the project outreach with the Organic Center's Google Ad Words Grant, which provides up to \$40,000 of funding per month for Google Ad Words. This campaign has generated a total of 275,027 clicks and 2,674,981 ad views over the last year. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Specific Goal Accomplishments 1. Provide a venue for a diverse array of organic farmers to directly convey their needs to AgTech innovators and to learn about new technologies that are being developed. One of the ways we achieved these goals was through the inclusion of mentors in the hackathon. The mentors included in the hackathon were: Project management mentors who evaluated the ability to complete tasks within the allotted time and prevent scope creep. They had understanding of funding, business, project management, and open source. Domain expert who evaluated the impact of the project. They had in depth understanding of organic agriculture, and were organic farmers that have leadership in the community. Tech mentors who evaluated the technical feasibility of the project Design mentors who evaluated the user experience and aesthetic of the project. These mentors shared needs of organic farmers and industry members to those in the tech sector, and tech and design mentors were able to share information with organic farmers about what was possible and directions to move toward the future in a joint capacity. We also achieved this goal during the conference portion of the project. For example, we heard from Amy Wu of From Farms to Incubators, who explained the role of storytelling in amplifying the voices and contributions of female innovators in the fast growing field of agtech, and bridging the gap between tech and farmers. Finally, we had talks from farmers such as Karen Washington, the owner of Rise & Root Farm. She noted not only the needs of farmers, but also the pitfalls that have arisen from past AgTech and the potential pitfalls we face in the future. 2. Identify tactics to enhance the accessibility and usability of expensive or specialized technology to small and low-resource organic farmers. To achieve this goal, we included a series of speakers focused on increasing technological accessibility for small farms. Specifically, we heard from David Selassie Opoku of Growing Gold Farms who spoke about the parallels between small farmers and subsistence farms; Jacki Perkins of MOFGA who spoke on the Shared-Use Farm Equipment Program that MOFGA developed; and Wade Miller of CROPP Cooperative who discussed how cooperative structures can increase tech access for farmers of all scales. We also heard from Laura Demmel Gilmer of OpenTEAM, Crystal Arsenault of Islands Organic Producers Association, Pablo Munoz Ledo of LookInto, and LaKisha Odom of FFAR, who explored the barriers to access in organic farming participation. They covered historical and current barriers and spoke from their experience and knowledge from farming, data gathering technology, land access, and barriers to collaboration in building technology. 3. Coordinate development and execute early stage open-source AgTech programs and prototype designs for organic agriculture through a hackathon. Two promising projects were conceptualized with one prototype developed. The concepts were presented in a show-and-tell fashion to the full group of hackathon participants, including farmer mentors who offered suggestions to make the concept more feasible and relevant for organic farmers, in addition to their enthusiasm for the work. Both teams consisting of programmers, farmers and researchers were motivated to continue meeting after this event to further develop their concepts and test

them in a participatory way with relevant, existing groups of organic farmers. There was interest in pursuing federal funding to support the full development of the following projects: Ecosystem Service Monitoring (ESM) tool This concept builds off the existing FarmOS open-source software tool that allows farmers to map their crop plans onto satellite imagery with a goal to assist in planning crop rotations and overall farm management. Farm OS would provide the platform to host the data collected for the Ecosystem Service Monitoring (ESM) tool with a goal of using the observation data for multiple purposes such as developing Organic System Plans, fulfilling NOP biodiversity guidance compliance, Organic certification compliance, and meeting conservation goals for USDA EQIP programs. The basic concept design is that farmers input their goals (e.g. conservation, biodiversity enhancement), and utilize quick forms that will facilitate data collection and offer suggestions of what to observe. Plans can be added to the FarmOS maps that will help the farmer work toward specific goals like adding cover crops or non-crop vegetative diversity. Progress can then be tracked through goals and milestones using on-farm observations across space and time, with the final step being that planned goals are realized. The (ESM) tool will produce final reports and data analysis that can be used for multiple certification/audit purposes, though the team recognized the challenge that one report may not work everywhere, even if just trying to satisfy once compliance (e.g. different organic certifiers may interpret rules/guidelines differently). Farmer mentors were enthusiastic about this project, particularly its open-source nature. Umbrella Worker's Cooperative The main focus of this project addresses the challenge that many farmers need to work a second job to earn enough income to sustain their household, particularly in the winter months in regions where the growing season is not year-round. The concept of an umbrella worker's cooperative would work in such a way that people could rotate jobs seasonally between coops as needed. Farmer mentors were extremely enthusiastic about this concept and saw this as hope for saving the future of farming as current farmers age out in a time when farming is not feasible or sustainable for younger generations, even if the interest exists. By recruiting new farmers, alternative practices such as organic, can be elevated as traditional non-organic farmers age out. 4. Develop strategies to increase continued partnerships between AgTech and farmers. This goal was achieved during both the conference and the hackathon. The conference not only brought together speakers from many sectors to discuss issues together Hackathon teams were developed with four team members: a domain expert, a project manager, designers, and developers. The domain experts hold in-depth knowledge about the problem and challenge domain. In this case the domain experts were farmers, who worked hand-in-hand with the hackathon teams. The project managers are responsible for organization, and hold expertise in project management. At our hackathon project managers ranged from industry members who are experienced with project management to researchers who are used to juggling multiple research projects. Developers and designers fall into the tech sector, and are responsible for desining the feel of the product, usability, and the nuts and bolts of function development (eg. data and content management). These diverse teams worked together, started projects, and built the scaffolding for continued partnerships between AgTech and Farmers. These strategies had amazing outcomes. At the end of the conference and hackathon the connections formed between farmers and AgTech professionals was deep, and long-lasting. One farmer noted to the AgTech developers during the hackathon \"I feel like you are all my new best friends.\" Another farmer noted: \"I was super skeptical about AgTech and this hackathon, but attending this hackathon has made me really inspired and hopeful about the future of organic and AgTech\" Publications Type: Websites Status: Published Year Published: 2022 Citation: Shade, J.. Organic Confluences Conference: Equity and Access in AgTech. The Organic Center. Retrieved Feb 26, 2022, from https://www.organic-center.org/AgTech Type: Websites Status: Published Year Published: 2022 Citation: Shade, J.. Organic Confluences Conference: Equity and Access in AgTech Speakers. The Organic Center. Retrieved Feb 26, 2022, from https://www.organic-center.org/organic-confluences-conference-equity-and-access-agtech-speakers-moderators Type: Other Status: Published Year Published: 2022 Citation: Raturi, A., M. Stenta, A. Sciligo, J. Norton, G. Austic, et al. 2022. GOAT Hack@Organic Miro Board. https://miro.com/app/board/uXjVOLUY078=/ Progress 09/01/20 to 08/31/21 Outputs Target Audience:Conference planning and organization has engaged a diverse combination of farmers, educators, industry leaders and scientists. Specifically, we have convened a Planning Committee meeting with Jessica Shade and Amber Sciligo of The Organic Center, Kelly Maguire of USDA ERS, Ankita Raturi of Purdue, and Alice Forminga of eOrganic. We also connected with a diverse advisory committee, including the following individuals to discuss the conference agenda and potential speakers (see below). Finally, weare in discussions with multiple farmer groups that represent marginalized farmers including the National Latino Farmers and Ranchers, Southeastern African-American Farmers Organic Network (SAAFON), and the food group, to ensure that a diversity of perspectives are represented in both the organization of the meeting as well panel speakers. Bob Quinn Kamut Ben Worley Agrisource Data Kathleen Merrigan ASU Danilo Leao BovControl Cindy Daley Chico State Erin Callahan Climate Collaborative Christina Volgyesi Dr. Bronner's Sebastian Boyer Farm Wise Labs Perry Clutts Farmer Advisory Council Michale O'Gorman Farmer Veteran Coalition Dorn Cox Farmhack, GOAT Michael Stenta FarmOS/Farmier Craig Ganssle Farmwave Mark Retzloff Flock Sara Clow Flock Marty Mesh Florida Organic Growers Danielle Nierenburg Food Tank Linda Cronin FSA Matthew Pavone FSA Alison E. Czeczuga Gaia Herbs Christina Owens General Mills Jeffry Orrey GeoVisual Analytics Mark Squire Good Earth Natural Foods David Vetter Grain Place Foods Emma Fuller

Granular Katie Clark Happy Family (Danone) Kathleen Delate Iowa State University David Nichols Loupe Jessica Lundberg Lundberg Family Farms Lori Stern MOSES Robin Schoen NAS Aaron Shier Nat Farmers Union Mark Nelson National Association of County Ag Agents Rudy Arrendondo National Latino Farmers and Ranchers Jennifer Tucker National Organic Program, USDA Cara Fraver National Young Farmers Coalition Dag Falck Nature's Path Foods Inc Jeff Schahczenski NCAT Carlotta Mast New Hope Lindsay Haines NRCS Cara Fraver NYFC Carolyn Dimitri NYU Dennis R. Buckmaster OATS, Purdue Sarah Brown Oregon Tilth Brise Tencer Organic Farming Research Foundation Logan Peterman Organic Valley/CROPP Cooperative Nicholas Andrews OSU Extension Greg Austic Our Sci LLC Cathy Jones Periwinkle farms Perry Clutts Pleasantview Farm Jefferey Moyer Rodale Institute Diana Martin Rodale Institute Katherine DiMatteo Sustainable Food Trade Org Kathryn DeMaster UC Berkeley Alexis Racellis University of Texas Pan Am Erin Silva University of Wisconsin, Madison Michael Cavigelli USDA ARS Steven Mirsky USDA ARS Penny Zuck USDA NOP Lindsay Haines USDA NRCS Michael Brautovich Whitewave Ann Marie Hourigan Whole Foods Michel Nischan Wholesome Wave Changes/Problems:We have encountered two major challenges to completing the goals of this project, but have found solutions to both of these challenges: 1. COVID-19 The pandemic has prevented in-person meetings from occurring, so we are pivoting to a virtual meeting. This provides opportunities to engage a broader audience, and we are hoping to leverage our network to ensure that voices from around the United States are heard. Unfortunately, this change has delayed our timeframe, so we are currently planning to hold the meeting in the fall of 2021 rather than our initially planned winter of 2021. 2. Disbandment of the Southern Sustainable Agriculture Working Group (SSAWG) We had originally planned to hold the conference in tandem with the SSAWG annual meeting, but unfortunately (and surprisingly) they closed their doors for the final time this summer. However, we have identified an alternate partner in the Midwest Organic and Sustainable Education Service (MOSES), who has agreed to co-house our two conferences. MOSES is an ideal replacement for the SSAWG annual meeting, because they also focus on diversity, equity, and inclusion, and ensure underrepresented farmer voices are heard. They are committed to ensuring this conference is developed in a way that meets the needs of disadvantaged farmers and avoids common pitfalls around inadvertent bias, racism and exclusion. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals?We plan to finalize the conference agenda, identify speakers, finalize venue logistics, advertise and complete registration, and hold the conference and hackathon. We also plan to report out to our audience about outcomes from the conference. Impacts What was accomplished under these goals? Provide a venue for a diverse array of organic farmers to directly convey their needs to AgTech innovators and to learn about new technologies that are being developed. We are in the process of developing a conference that will bring together farmers, developers, AgTech innovators, and researchers. We have reached out to several developers and members of the AgTech industry as well as organic growers and industry members to engage them in the planning process. We had originally planned to partner with the Southern Sustainable Agriculture Working Group, but they disbanded, so we have identified a new partner conference with the MidwestOrganicand Sustainable Education Service (MOSES) annual meeting. This meeting draws over 2,500 attendees. The conference will be a hybrid event with meetings taking place both in person and remotely to allow for participation across multiple groups. Specifically, we have met with MOSES staff to organize a hybrid even that will allow remote participants as well as in-person participants through virtual panels in combination with on-site workshops. We are also working with them to secure a central room and several break-out rooms for the hackathon so that programmers can interact seamlessly with the full MOSES conference along with the hackathon event. Identify tactics to enhance the accessibility and usability of expensive or specialized technology to small and low-resource organic farmers. Strategize on the design of scale-agnostic AgTech, and determine means to overcome generational, language and technological literacy-based challenges. Our proposed agenda addresses issues of access and inclusion, and we are currently working with stakeholders to identify potential speakers for the event. For example, panels will include \"Increasing Technological Accessibility for Small Farms,\" which will highlight successful pathways and potential opportunities for small farmers to have increased access to technology; \"Equitable AgTech: Advancing Tech for All,\" which will identify pathways and opportunities for all farmers to have increased access to technology, focusing on aspects such as cost barriers and technological literacy; and \"Incorporating Tech into Organic Ideals,\" which will explore methods to evaluate the compatibility of future AgTech with organic ideals. We are in discussions with multiple farmer groups that represent marginalized farmers including the National Latino Farmers and Ranchers, Southeastern African-American Farmers Organic Network (SAAFON), and the food group, to ensure that a diversity of perspectives are represented in both the organization of the meeting as well panel speakers. Coordinate development and execute early stage open-source AgTech programs and prototype designs for organic agriculture through a hackathon conducted in partnership with the Gathering for Open Agricultural Technology (GOAT). We are organizing a hackathon with the Gathering for Open Agricultural Technology (GOAT). We have had an initial meeting and exchanged several emails with our point person within GOAT, and are setting up a meeting with the full GOAT team to identify local hubs so that we can have a mix of central programming at the MOSES Annual Meeting, as

well as remote programming at local sites. We have developed a draft call for programmer participants and identified challenge areas for programmers to consider as teams are developed. Prompt questions will be delivered to farmers who can then engage with programmers to jointly develop solutions to challenges they face. Here is the call: Hack @ Organic Background Because organic farmers are banned from using common conventional materials such as most synthetic pesticides and fertilizers, the tools available to tackle common agricultural challenges are limited. Agricultural technology (AgTech) could provide sustainable, organic-compliant methods to overcome organic obstacles, but there need to be more organic-AgTech collaborations. In addition to this need, the diversity of organic farming operations presents the need for AgTech discussions to include issues such as accessibility of technology for small and/or low-income farms, equity around tech use and adoption, and inclusion of marginalized farming communities in the development of AgTech. The goal of a Hack @ Organic would be to bring together a multidisciplinary cohort of researchers, designers, developers, and agricultural practitioners to develop equitable, open source technical infrastructure that enables research, adoption, and evaluation of organic agricultural practices. Challenge areas · Organic compliance and record keeping o Prompt question: Walk us through how you keep your records for organic certification. Organic operations are required to track detailed information for organic certification and compliance. This type of software could streamline tracking for compliance. · Supply chain traceability o Prompt question: What goes into getting your crop from the field to the consumer? Innovative software focused on documentation of farm management decisions can manage everything from crop plans and inputs, to tracking costs and sales. This technology may be especially helpful for diversified crop operations, which are common for organic farming operations. Farm-to-table block chain technology can enable secure traceability of a product along the entire supply chain and assist in fraud prevention. This would also be critical for addressing and overcoming disturbances in the food flow from field to consumer. · Tracking ecosystem service goals o Prompt question: What environmental goals are you interested in and how do you track them? Ensuring that a farm is supporting a healthy ecosystem requires tracking of sustainability goals. These tools would target variables such as soil health, carbon sequestration, biodiversity, etc. · Robotic and sensing technologies o Prompt question: How do you address on-farm challenges such as weeds, insect pressures, ect.? What are the most labor-intensive parts of your production? Robotic and sensing technologies that can reduce the labor burden for organic farmers by addressing issues such as on-farm monitoring, weed control and harvest. New robotic technologies are being developed to automate activities such as pruning and harvest. Sensing technologies such as drones and remote monitoring devices can optimize resource use on farms of all sizes by providing high resolution, real time data that can be used to monitor pests, pathogens and weeds, track soil health and irrigation needs, and estimate crop yields. · Innovative machinery that improves efficiency and cost effectiveness. o Prompt questions: Starting from when you first decide to plant a crop, what goes into soil management, planting, growing, and harvesting the crop? OR (for meat/dairy) Walk us through how you manage your animal throughout the process of your product. For example, a recent study by Frasconi et al.found that combining flaming and roller crimping was the most effective and sustainable way to terminate cover crops without tillage. Additionally, a current machine developed in Australia called the Harrington Seed Destructor simultaneously vacuums and pulverizes weed seeds as a non-chemical method of weed control. It is currently being testing in limited locations in the US. Develop strategies to increase continued partnerships between AgTech and farmers. Part of our development strategy with GOAT will be to organize multisector teams (including farmers, AgTech innovators, programmers and other organic stakeholders) who will participate jointly in the hackathon. These farmer-driven teams will coordinate and inspire development of AgTech for organic priorities and needs across agricultural scales, for diverse systems and people, and use participatory development methods. Publications

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Northeast Organic Seed Conference: Strengthening the Regional Organic Seed Sector

Accession No.	1023587
Project No.	VT0092CG
Agency	NIFA VT.\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51300-32195
Proposal No.	2020-02160
Start Date	01 SEP 2020
Term Date	31 AUG 2021
Grant Amount	$49,974
Grant Year	2020
Investigator(s)	Tobin, D.; Von Wettberg, ER, .; Reynolds, TR, W..

NON-TECHNICAL SUMMARY

This project focuses on strengthening the organic seed sector in the U.S. Northeast, essential given that extensive activities related to organic seed production and distribution in the region are largely disconnected. Building upon the existing Northeast Organic Seed Conference (NOSC), we seek to create synergies across components of the organic seed system and position stakeholders to pursue collaborative, strategic initiatives that are demographically inclusive and ecologically resilient. Particular focus will be on recruiting underrepresented populations to participate in the 2021 NOSC to ensure the full range of voices are included in planning for the region\'s organic seed system. The purpose of this grant emerged from the perspectives of key organic seed system stakeholders in the Northeast who have been actively involved in the previous two NOSCs. Collectively, they identified two essential needs that need to be addressed: 1) diversify the participants at NOSC and 2) link the myriad organic seed-related activities occurring in the region. A planning committee with extensive backgrounds and experience in the Northeast organic seed system and who represent diverse perspectives will organize and coordinate recruitment of NOSC participants, conference-related activities, and assessments. The project will generate a strategic plan that identifies the diverse stakeholders engaged in the Northeast organic seed system, explores opportunities to enhance the scope of production and distribution of seed via commercial and non-commercial channels, and highlights synergetic partnerships. This project seeks to strengthen the Northeast region\'s organic seed sector through increasing access to regionally and culturally relevant seed, fostering connections among seed system stakeholders with specific attention to underrepresented populations, identifying market opportunities for seed producers and distributors, and closing gaps between demand for and supply of organic seed.

OBJECTIVES

The goal of this conference grant is to bolster the Northeastern (Maine to Pennsylvania) organic seed system by bringing together diverse stakeholders at the 2021 Northeast Organic Seed Conference (NOSC), held biennially in conjunction with the annual NOFA-NY conference, to share experiences, build trust and identify opportunities for collaboration, and enhance the resilience of the region\'s organic seed system genetically, socially, and economically. Specifically, objectives of this proposal include:Objective 1. Diversify participation in the 2021 NOSC conference, ensuring at least 35 participants are from tribal communities, refugee farmer groups, seed savers of lower socioeconomic status, and/or other underrepresented groups (including youth and

students);Objective b. Identify barriers and opportunities to fortify the Northeast organic seed system; Objective c. Develop strategies to address these barriers and opportunities; Objective d. Create synergies among stakeholders across the organic seed system (including production, distribution, marketing, policy, research, education, and outreach); andObjective e. Facilitate continued communication and iterative planning after the conference.

APPROACH

The achievement of the objectives will require multiple methods.To organize the 2021 NOSC, we will rely on a participatory process based in regular meetings (at least monthly) among the core committee members and semi-regular meetings (at least every other month) with the advisory committee. These meetings will occur using telephone or video conferencing technology and will be evaluated based on the number of meetings that are held and the successful implementation of the NOSC. To recruit underrepresented populations, the core and advisory committees will leverage both their informal networks (i.e., personal connections) and more formal networks (i.e., listservs maintained by organizations). The effectiveness of recruitment activities will be assessed through the number of NOSC participants generally and number of underrepresented participants specifically. Participants will assess their experiences with the 2021 NOSC, including new networks/collaborative opportunities to which they've been exposed, through online surveys, the results of which will be analyzed, summarized, and made available to the conference participants. Open forums during the 2021 NOSC will serve as the basis of a regional strategic plan that will be made available and open to conference participants to contribute in order to maintain continued communication and collaboration. This document will serve as a baseline for future evaluations. **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience:This grant revolved around planning and implementing the 2021 Northeast Organic Seed Growers Conference (NOSGC). The 2021 conference was the third iteration of the NOSGC and this grant sought to address priorities of previous participants, namely to diversify participation among those who had historically not been sufficiently represented at the conference. The target audience were those were primarily seed growers, both commercial and non-commercial, though other stakeholders with interest in seed production, including researchers, plant breeders, seed companies, community-based organizations, and non-profits, were also part of the targeted audience. In particular, the project's efforts placed emphasis on underrepresented populations (BIPOC, LGBTQ+, lower socioeconomic status, students etc.) to diversify participation and representation at the NOSGC. To do so, applications from individuals from underrepresented populations were reviewed and those who met the criteria were provided with free conference registrations supported by this project. Changes/Problems: The Covid-19 pandemic prompted the major change for this project. Originally intended as an in-person conference, the NOGSC was shifted to a virtual format. This shift had several implications. First, it required buy-in from the volunteers who were helping to organize and implement the conference and required additional preparation among presenters through practice sessions, as well as enhanced technical support during the conference. Given these changes, a poster session was ultimately excluded from the conference agenda. In terms of the free registrations that this project supported, the initial proposal was to offer 35 scholarships that would support conference registration and travel. Given that travel was no longer required, and registration was lower than in previous years given the online format, we were able to increase the number of free registrations provided up to 91, which further diversified participation at the conference. What opportunities for training and professional development has the project provided? Professional development lay at the basis of the conference sessions. Among the sessions offered included: seed saving 101, plant pathology of common Northeast seed crops, sourcing germplasm, and dissemination of new varieties. How have the results been disseminated to communities of interest? Data are currently being processed and analyzed and the results will be disseminated back to conference participants and other important seed system stakeholders in early 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? Seeds are vital to food production, food security, climate adaptation, and the cultural acceptability of food. Given their importance, strengthening local and regional seed systems is an essential undertaking to enhance food system resilience. In the Northeast, there is a great deal of current seed work being undertaken, both commercially and non-commercially, but these activities remain largely disconnected. Part of the intent of the biennial NOGSC is to make connections across the region, but a self-identified concern among previous participants is that the attendance lacked diversity, thus limiting the perspectives represented. This project sought to diversify participation at the 2021 NOGSC and learn from these various perspectives to compile a needs assessment of the regional strengths, opportunities, weaknesses, and challenges. Objective a. Although a difficult pivot, the format change - from in-person to virtual - of the 2021 NOGSC was effective in enhancing access to the conference. At the 2019 NOGSC, 70 people attended the in-person conference; in 2021, 387 individuals attended. Among those who provided demographic information, 11 identified as Black or African-American, 11 as Indigenous/First Nations, 7 as Asian/Southeast Asian, 8 as Latinx, 30 as part of the LGBTQ community, 23 as low-income, 8 as immigrants or 1st generation, 4 as veterans, and 5 as physically disabled. To promote this diversity at the conference, a key aspect of this project

was to provide free conference registrations to individuals who both engage in seed work and represented populations that had been underrepresented at previous NOGSC iterations. In total, 91 free registrations were provided, including to 23 who identified as Black, 8 as Indigenous, and 8 students. The diversity in participation in participants was also reflected in conference presenters, which included representation from Native American, Black, Latinx, Asian, and LGBTQ communities. Objective b. To compile information relevant for a needs assessment, notes were taken at 17 conference sessions, a full day workshop was dedicated to a needs assessment exercise, and a post-conference survey was conducted (n=115, 30% response rate). Using these data sources, particular challenges in the regional seed system identified by participants included the ability to earn a livable wage through seed work, lack of employment opportunities in the commercial seed sector, a lack of access to land, high informational and knowledge requirements to scale and formalize seed production, and the complexity of legal and policy institutions governing seed systems. In addition, concern was also expressed regarding the lack of expertise in universities focused on plant breeding and seed production, especially geared towards diverse audiences. Preliminary findings from the post-conference survey provide further evidence of these challenges and other related challenges. Over 50% of respondents indicated that lack of time (64.28%), lack of financial capital (67.34%), and legal regulations around seeds (51.65%) were either challenging or very challenging. Another prominent challenge were the stresses the seed system experienced due to Covid-19. Conference participants indicated that the pandemic increased demand for seed in both commercial and non-commercial sectors but they didn't have the support they needed to meet these demands, like labor and adequate channels for sourcing seed. The opportunities identified by participants focused on the importance of building connections and networks across the region. Attendees expressed enthusiasm to share contact information, resources, and other kinds of support. In addition, there was an openness to address areas of tension between groups and power dynamics, especially around conversations of cultural relationships to seeds and resource distribution. Attendees, many of whom were white, were open with their desire on learning how to better navigate conversations and problems of racial inequality in the seed system. Preliminary survey results support qualitative observations regarding the energy around building the social infrastructure of the regional seed systems. Among survey respondents, 100.0% indicated they were interested or very interested in connecting with people from a different generation, 99.07% indicated they were interested or very interested in connecting with people of different races and ethnicities regarding seed work, and 99.07% were interested or very interested in connecting to people in a different state. In particular, interest in making these connections were driven by the desire to "learn about other kinds of seed work that I am not involved in,\" \"collaborate on research and experimentation,\" and \"share cultural meaning around seed.\" Objective c. Across data collection activities, several specific ideas emerged to address the articulated barriers and opportunities. Participants articulated several areas of focus for future educational programming that would address both barriers to entry in selling seeds to seed companies and navigating legal policy. Survey respondents indicated that they would be most interested in educational opportunities covering: seed cleaning, seed quality tests, disease prevention and management, tools and equipment for processing seed, and intellectual property rights. Participants also indicated that strategies to mitigate future seed shortages include enhancing the distribution infrastructure in the region, with investments in seed libraries serving as one possibility to do so but also further engagement from universities in serving as a partner to help disseminate seeds and the develoment of seed cooperatives. Repeatedly, educational and training opportunities were highlighted as critical to pass on knowledge to younger and new seed savers. The Organic Seed Alliance has an internship model that could provide a model for any regional efforts. In order to continue to build regional networks, participants reaffirmed the importance of NOSGC. Among survey respondents, 96.88% indicated that they were satisfied or extremely satisfied with their experience at the conference. However, at the same time, participants also indicated that the NOSGC alone could not be relied upon to build regional networks and other strategies needed to be pursued including social media and partnering with universities. Across all strands of data collection, participants articulated the importance of more funding being made available to actualize these strategies. Objective d. An important guiding principle to the planning of the conference was to pursue this objective. As such, presenters represented various sectors in the seed system, including plant breeders, farmers, gardeners, seed companies, non-profits, community-based organizations, and researchers. Among the 31 attendees at the full-day needs assessment exercise, which was designed to foster interaction among stakeholders across the system, representation existed among community-based seed organizations, home-based seed workers, farmers who save seeds, plant breeders, seed companies, and seed producers. In addition to sessions focused on technical skills and knowledge, other sessions were organized around making connections: a general meet-up for Northeast seed growers, a meet-up for Indigenous seed savers, a session to meet and discuss contracts with seed companies, and a session to interact with seed activists and non-profits. Objective e. Although achieving this objective is ongoing, planning for the 2023 NOGSC is already underway. Several new partnerships emerged from the seed conference, with several grant proposals currently in process. As the data are further processed and analyzed, a report will be generated and disseminated to all participants as a basis for discussion at the 2023 NOGSC to inform iterative planning.
Publications

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Managing Organic Forages in a Changing Climate

Accession No.	1023752
Project No.	VTN0012
Agency	NIFA VT.N\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51300-32365
Proposal No.	2020-02129
Start Date	01 SEP 2020
Term Date	31 AUG 2021
Grant Amount	$49,904
Grant Year	2020
Investigator(s)	Darby, H. M.; Soder, KA, J..; Brito, AN, .; Riday, HE, .; Williamson, JE, .

NON-TECHNICAL SUMMARY

Forages are the backbone of livestock production. Farmers must produce both high yield and quality feed to sustain the herd through the year without sacrificing milk quality, and animal health and productivity. Forage production and quality can be highly variable if the system is not intensively managed. Mitigating this risk involves understanding soil health, nutrient cycling, grazing management, species selection, and the relationships between all these aspects and farm economics. This complex issue therefore must be addressed through multiple strategies that can increase farm resiliency, especially under increasingly challenging climatic conditions, and maximize on farm forage production and quality. Unlike commodity crops (e.g., corn, soybeans, wheat) forage crops do not have a cohesive industry and commodity support system that helps determine and fund critical research and education. As funding and land-grant university faculty numbers decline, there is an emerging need to unite forage specialists and key stakeholders to develop forage research priorities that address the current and future needs of farmers and support viable forage-based dairy production across the U.S. This proposal addresses these gaps by using surveys, stakeholder meetings, and focus groups to identify critical research, extension, and education needs. The culmination of this project will be a forage research agenda, published needs assessment, and grant proposal(s) that address the needs identified through this project.

OBJECTIVES

As the number of forage agronomists, specialists, and technical service providers decline, the number of people able to carry out the research, education, and outreach that is critical to supporting the viability of the organic dairy industry is also declining. Without these individuals, secondary education and technical service provider training programs related to forages will be less available, further reducing the future capacity in this field. In identifying research and extension needs, we also must identify gaps in personnel numbers, skills, and knowledge. By addressing these gaps, we will be better able to carry out the research and extension efforts needed to further the organic dairy industry into the future.Project objectives: Our diverse team with the guidance of our major stakeholders aims to improve organic forage management and the economic viability of the organic dairy industry through the following objectives: Objective 1: Understand the critical forage knowledge gaps and resource needs of organic dairy farmers to help build resiliency and viability of those farms into the future via a national survey and focus groups. Objective 2: Prioritize identified needs and develop research priorities and outreach that are integral in protecting and expanding our forage knowledge, especially under a changing climate through a focused researcher meeting. Objective 3: Develop a research and outreach agenda that leads to

further collaborations of the team to develop grant proposal(s) and resource materials that addresses the needs identified through this project to further forage knowledge and farm viability.

APPROACH

1. and 2. Description of proposed activities and methodsObjective 1: Survey and Focus GroupsIn order to understand both of these dynamics impacting farmer forage knowledge and implementation, a national survey of organic dairy farmers will be conducted. We expect at least 300 farmers from across the country to participate in the survey, based on our previous response rates, providing valuable insight into farmer forage knowledge and resource needs. The results of the survey will be presented at the research meeting, focus groups, and published in a peer-reviewed journal. A team of scientists and practitioners from different disciplines in the forage community will define the precise information to be collected via the survey, as well as the appropriate wording for the questions and the ranking criteria. The survey will provide an assessment of needs while ensuring the anonymity of respondents to encourage uncensored responses. To guarantee a good response rate (\>30%), we will use a letter of endorsement from highly reputable nationwide associations in industrial hemp and we will use the three-wave-method of survey, reminder, and survey. We will secure IRB approval before conducting the survey.The rationale for focus groups is that they enable participants to explain: 1) the problem, 2) how they attempt to remedy or cope with the problem, 3) the effects of the problem on their operation and economic situation, and 4) the effects of the problem on the environment. Focus groups provide a great deal of descriptive information about a particular set of issues with only a modest number of interviewsParticipants for the focus groups will be drawn from multiple mailing and email lists that include organic dairy farmers \e.g., NODPA, Organic Valley, and publicly available National Organic Program lists). In addition, leaders from industry and nonprofit organizations (e.g., MOSES, Grassworks) and University extension staff will be asked to provide names of key individuals involved in the organic dairy industry. Focus group meetings will be hosted at 2 sites targeting geographical areas of substantial organic dairy production in the NE and MW. The most likely sites will be NY in the NE, and WI in the MW. However, the planning team will invite farmers from other states and locations will be chosen to maximize farmer participation. Each focus group will include 20 to 30 participants with attention paid to a balance of farmers, industry representatives, gender/ethnic representation, and length of time involved in organic production. Focus group questions will be developed by planning personnel as a very general set of draft questions and will be modified based upon feedback from a few key stakeholders and planning grant collaborators. Facilitators for the focus groups will include planning personnel and extension staff from each site with evaluation expertise. Each focus group will be conducted in a similar manner, with the facilitator providing a brief introduction of the goals of the study, the ground rules, and instructions to obtain consent from participants. Eight to 10 open-ended questions will be asked and the facilitators will ensure all participants respond, drawing out members when necessary, and politely closing off dominant participants if required (Groves et al.,2004). The sessions will be recorded to ensure comprehensive capture of input. Notes from each focus group will be reviewed for obvious location-specific differences, and these differences, if any, will be noted.Objective 2: Researcher meetingIdentifying forage research and outreach priorities is crucial to furthering forage knowledge, education, extension, and future support. Forage needs identified through the survey and focus groups will provide the platform for developing the research and outreach agenda at the researcher meeting. The meeting will be held in a central location and will bring together agronomists, breeders, extension, research, and other industry professionals involved in forage-related research efforts to discuss the knowledge and resource gaps identified in Objective 1. During the meeting, the group will identify specific research priorities that will address the needs identified by farmers. Particular attention will be paid to research concerning forage performance under a changing climate.Objective 3: Forage Research and Outreach Agenda and Grant SubmissionsThis project will ultimately culminate into a forage research and outreach agenda with a planned implementation schedule. Researcher and extension teams will be formed to develop and submit proposals to OREI in 2021 as well as potential proposals to the ORG program and other USDA NIFA grant opportunities. The research agenda will be available through project PIs websites. **Progress** 09/01/20 to 08/31/22 **Outputs** Target Audience:The target audience of this project is organic dairy farmers and organic forage producers in the United States. Dairy farmers are seeking information about successful management of high-forage dairy systems that maintain herd health and production, milk quality, and farm economics in an increasing erratic climate. The decline in forage expertise and lack of funding and support for forage research and extension work threatens our ability to support a viable organic dairy system into the future, as well as other forage-based livestock systems. The proposed project would generate essential information for both farmers, extension, researchers, and technical service providers across the country to support successful and viable organic high-forage dairy systems. Changes/Problems: A no cost extension was requested to be able to complete all project deliverables. The pandemic created many challenges and our team was unable to carry out the project as originally planned. Originally, we had planned to hold the focus groups in-person following the completion of the survey and meeting of the research team. However, due to limitations of travel and in-person meeting with regard to the COVID-19 pandemic, the focus groups were held

virtually. We were delayed in transitioning to a virtual approach because we had hoped that an in-person option might become a reality. As time progressed, we decided it was in our best interest to proceed with a virtual event. We had initially hoped to host the meetings and outreach in collaboration with other organic conference around the country. Again because these were cancelled we had to reformulate an action plan to complete the work. At this point the project is well underway and will be completed by the new end date. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest? The Focus groups were held virtually on April 21 and 23, 2021. The Focus Group meetings included organic dairy farmers and organic dairy stakeholders from throughout the United States. There were 24 participants representing organic dairies in 8 states. Through the Focus Groups we were able to share the goals of the overall project and gather critical feedback on the forage research and outreach needs of the organic dairy industry. The Focus Groups were recorded and notes were also taken. The Focus Group preliminary result were shared with attendees in May. Events: • Virtual focus group 1- 4/21/21 11:30am-1pm EST via Zoom. 9 attendees. • Virtual focus group 2- 4/21/21 3-4pm EST via Zoom. 6 attendees. • Virtual focus group 3- 4-23-21 1-2pm EST via Zoom. 9 attendees In addition, there have been multiple press releases and presentations that were able to share project goals and promote the national needs survey. • NODPA Field Days, October 1st, 2021. Presentation titled: Invest in your forages like your dairy depends on it because it does. Presentation included information about the project and focus group results and in-print surveys were made available to attendees. • NODPA Newsletter, November, 2021. Press Release to promote organic farmers completing the forage survey. • Organic Broadcaster Newsletter through MOSES, November 2021. Press Release to promote organic farmers completing the forage survey. Finally, following the researcher meeting in February and March of 2022, the team developed a peer reviewed publication and a research brief that was made available to stakeholders through field days, conference presentations, newsletter articles, and on websites. The materials directly reached 357 stakeholders. Eric Hatungimana, Heather M. Darby, Kathy J. Soder, Sara E. Ziegler, Andre F. Brito, Lisa Kissing Kucek, Heathcliffe Riday, and E. Charles Brummer. 2023. Assessing forage research and education needs of organic dairy farms in the United States. Renewable Agriculture and Food Systems Journal. Awaiting Publication. Eric Hatungimana, Heather M. Darby, Kathy J. Soder, Sara E. Ziegler, Andre F. Brito, Lisa Kissing Kucek, Heathcliffe Riday, and E. Charles Brummer. 2022. Assessing forage research and education needs of organic dairy farms in the United States. University of Vermont Extension Publication. https://www.uvm.edu/sites/default/files/Northwest-Crops-and-Soils-Program/2022%20Research%20Reports/OREI_Forage_Survey_Highlights_FINAL.pdf Heather Darby and Sara Ziegler. 2022. Best strategies during times of high grain prices and unstable climate. Northeast Organic Dairy Producers Alliance Annual Conference. 29-30 August, 2022. Middlebury, VT. 97 attendees. Bill Kipp, Heather Darby, and Sara Ziegler. 2022. Best nutrition strategies during times of high grain and input costs. Northeast Organic Dairy Producers Alliance Newsletter. vol. 22 issue 6. Heather Darby and Sara Ziegler. 2022. UVM Forage and Dairy Research Organic Dairy Conference. Feb 24, 2022. Burlington, VT. 102 attendees. Heather Darby, Sara Ziegler, and Sarah Flack. 2022. Focus on Forage Field Day. Fairfield, VT. June 17, 2022. 45 attendees. Heather Darby, Sara Ziegler, and Sarah Flack. 2022. Organic Dairy Field Day. Strafford, VT. July 26, 2022. 62 attendees. Heather Darby, Sara Ziegler, and Sarah Flack. 2022. Organic Dairy Field Day. Claremont, NH. Aug 1, 2022. 51 attendees. 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: Understand the critical forage knowledge gaps and resource needs of organic dairy farmers to help build resiliency and viability of those farms into the future via a national survey and focus groups. An IRB approval was received by the University of Vermont for both the Focus Groups and Survey on 15- March, 2021 (STUDY00001501). Due to limitations of travel and in-person meeting with regard to the COVID-19 pandemic, the three focus groups were held virtually in late April , 2021. A total of 24 dairy farmers and related stakeholders from VT, NY, ME, VA, WI, MN, OR, and CA participated in the virtual focus groups. Prior to the meetings, a short survey was sent to each participant. At the meetings, the results of the short survey were shared with participants to help prepare for and facilitated discussion. We utilized the Dillman tailored design approach to disseminate the survey in print to 650 farms from a list of producers obtained from organic dairy processors and associations located in New Hampshire, New York, Wisconsin, and CA. (Dillman et al., 2016). Follow-up was done through dairy processors and associations through 4 follow-up mailings either through listserves or mail. A total of 165 respondents returned the survey resulting in a response rate of 25% of the direct distribution. The survey consisted of eight sections including a) demographic and general farm information, b) forage systems and forage management, c) impacts of forage systems on dairy production, d) factors affecting farm forage system, e) weather-related impacts on farm's forage system and strategies to mitigate those impacts, f) producer-perceived knowledge that may limit their ability to achieve farm goals, g) frequency of utilization of available tools/information resources to support forage program decision-making, and h) knowledge and skills needed by producers for forage production and management. Demographically, 53% of the respondents self-identified as belonging to plain-sect communities. Nearly all (96.6%) of respondents were organic dairy farmers and 2.4% only produced organic forage.The majority of respondents (89%) managed herds between 11 and 200 cows. Objective 2: Prioritize identified needs

and develop research priorities and outreach that are integral in protecting and expanding our forage knowledge, especially under a changing climate through a focused researcher meeting. Forage needs identified through the survey and focus groups provided the platform for developing the research and outreach agenda at the two-researcher meetings held virtually in February and March of 2022. During the meeting, the group focused on research priorities that will address the needs identified by farmers. Objective 3: Develop a research and outreach agenda that leads to further collaborations of the team to develop grant proposal(s) and resource materials that addresses the needs identified through this project to further forage knowledge and farm viability. This project culminated into a peer-reviewed paper and research brief published for stakeholders that outline organic forage management systems, education opportunities, and research needs to promote the sustainability of the dairy industry. A researcher and extension team has been formed to develop and submit a proposal to OREI in 2023. Several proposals were submitted and recently awarded based on priorities outlined in the research report to USDA SARE (\$175,000), NRCS Conservation Innovation Grant program (\$285,000), and the Organic Valley Farmers Advocating for Organic grant program (\$47,000) in 2022. The following research and education priorities were identified through the survey and focus groups. Organic dairy producers indicated they needed skills in pasture renovation and rotation with reduced or no-tillage. Regarding pasture fertility management, producers indicated they needed more information on cost-effective fertility sources that can be used to fertilize forage pasture fields. Producers also needed to know how to fertilize forage pasture fields with manure and composting with micronutrients. Concerning forages and forage mixtures, producers indicated the need for information on forage varieties, forages mixtures, or forage-legume mixes that are more dual-purpose that begin production earlier in spring and later into fall, or that are more resilient under different weather conditions (too wet or too dry). Additionally, producers indicated the need for research-based information about harvest timing for optimum quality, cultivar and variety information for pasture seeding, forage trials on diverse soil, and new forage species. They would like more information on new advances from forage breeding and production results for organic systems. Moreover, producers highlighted the need of information about weed control in corn, timing for seeding, nurse crop decision making, general crop management, and updating the nutrient management plan. Information on farm equipment and equipment access was revealed by producers to be also an important knowledge they needed. For educational purposes, visual aids and tools for education and management were indicated to be important. For example, producers indicated that pictures of miscellaneous forages showing optimal harvest timing and field education through pasture walks would help improve their knowledge and skills. Among important topics of forage research and education needs, the focus groups identified four major research areas. The first research and education need concerned climate change resilience. The focus group highlighted research needs on water and nutrient use efficiency at the farm level. Moreover, research on forage species and varieties that are resistant to pest and diseases, and forage varieties that are resistant to drought and heat during summer months were of paramount importance. In addition to research on forages that are resistant to drought, research on factors affecting winter survival of forages is important as is the identification of new forage mixtures to increase forage yields and carbon sequestration, or to mitigate greenhouse gas emissions. In this regard, focus groups reported research needs on forage diversity that can adapt to local and regional environmental conditions, as well as research on soil biology connection to forage productivity and quality. The second research and education need was improving forage quality. As indicated by focus groups, research on forage quality should encompass forage nutrient concentrations of energy, sugar types, minerals, non-starch carbohydrates, and pectin. Moreover, evaluation of fiber digestibility and its relative volatile fatty acid (i.e., acetate) production and absorption versus milk butterfat content, and milk yield per ton of forages should be other research areas of interest. Research on forage quality should also focus on harvesting time for optimum nutrient content, forage storage, forage inventory management, and nutrient management. The third area of research and education need was to evaluate economic returns from soil fertility/soil health and the evaluation of economic returns from pasture renovation. There might be costs associated with maintaining soil fertility or pasture renovation, but limited research is available on economic returns from those efforts. Lastly, the focus groups indicated research needs on legumes for grazing, persistent perennial ryegrass, and corn that has a gametophyte factor to prevent cross pollination with transgenic varieties. Additionally, research on late maturity of forages and subsequent effects on nutrient content and nutrient digestibility is needed. Alternatives to common or traditional forages, research on novel forage species was also considered to be of high importance.
Publications - Type: Journal Articles Status: Awaiting Publication Year Published: 2023 Citation: Eric Hatungimana, Heather M. Darby, Kathy J. Soder, Sara E. Ziegler, Andre F. Brito, Lisa Kissing Kucek, Heathcliffe Riday, and E. Charles Brummer. 2023. Assessing forage research and education needs of organic dairy farms in the United States. Renewable Agriculture and Food Systems Journal. Awaiting Publication. - Type: Other Status: Published Year Published: 2022 Citation: Eric Hatungimana, Heather M. Darby, Kathy J. Soder, Sara E. Ziegler, Andre F. Brito, Lisa Kissing Kucek, Heathcliffe Riday, and E. Charles Brummer. 2022. Assessing forage research and education needs of organic dairy farms in the United States. University of Vermont Extension Publication. https://www.uvm.edu/sites/default/files/Northwest-Crops-and-Soils-Program/2022%20Research%20Reports/OREI_Forage_Survey_Highlights_FINAL.pdf - Type: Conference

Papers and Presentations Status: Published Year Published: 2022 Citation: Heather Darby and Sara Ziegler. 2022. Best strategies during times of high grain prices and unstable climate. Northeast Organic Dairy Producers Alliance Annual Conference. 29-30 August, 2022. Middlebury, VT. - Type: Other Status: Published Year Published: 2022 Citation: Bill Kipp, Heather Darby, and Sara Ziegler. 2022. Best nutrition strategies during times of high grain and input costs. Northeast Organic Dairy Producers Alliance Newsletter. vol. 22 issue 6. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Heather Darby and Sara Ziegler. 2022. UVM Forage and Dairy Research Organic Dairy Conference. Feb 24, 2022. Burlington, VT. **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience: The target audience of this project is organic dairy farmers in the United States. Dairy farmers are seeking information about successful management of high-forage dairy systems that maintain herd health and production, milk quality, and farm economics in an increasing erratic climate. The decline in forage expertise and lack of funding and support for forage research and extension work threatens our ability to support a viable organic dairy system into the future, as well as other forage-based livestock systems.The proposed project would generate essential information for both farmers, researchers, and technical service providers across the country to support successful and viable organic high-forage dairy systems. Changes/Problems: A no cost extension was requested to be able to complete all project deliverables. The pandemic has created many challenges and our team was unable to carryout the project as originally planned. Originally, we had planned to hold the focus groups in-person following the completion of the survey and meeting of the research team. However, due to limitations of travel and in-person meeting with regard to the COVID-19 pandemic, the focus groups were held virtually. We were delayed in transitioning to a virtual approach because we had hoped that an in-person option might become a reality. As time progressed, we decidied it was in our best interst to proceed with a virtual event. We had initally hoped to host the meetings and outreach in collaboration with other organic conference around the country. Again because these were cancelled we had to reformulate an action plan to complete the work. At this point the project is well underway and will be completed by the new end date. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest?The Focus groups were held virtually on April 21 and 23, 2021. The Focus Group meetings included organic dairy farmers and organic dairy stakeholders from throughout the United States. There were 24 participants representing organic dairies in8 states. Through the Focus Groups we were able to share the goals of the overal project and gather critical feedback on the forage research and outreach needs of the organic dairy industry. The Focus Groups were recorded and notes were also taken. The Focus Group preliminary result were shared with attendees in May. Events: Virtual focus group 1- 4/21/21 11:30am-1pm EST via Zoom. 9 attendees. Virtual focus group 2- 4/21/21 3-4pm EST via Zoom. 6 attendees. Virtual focus group 3- 4-23-21 1-2pm EST via Zoom. 9 attendees In addition, there have been multiple press releases and presentations that were able to share project goals and promote the national needs survey. NODPA Field Days, October 1st, 2021. Presentation titled: Invest in your forages like your dairy depends on it because it does. Presentation included information about the project and focus group results and in-print surveys were made available to attendees. NODPA Newsletter, November, 2021. Press Release to promote organic farmers completing the forage survey. Organic Broadcaster Newsletter through MOSES, November 2021. Press Release to promote organic farmers completing the forage survey. What do you plan to do during the next reporting period to accomplish the goals?Objective 1:Understand the critical forage knowledge gaps and resource needs of organic dairy farmers to help build resiliency and viability of those farms into the future via a national survey and focus groups. In the next reporting period we will close the survey and compile and analyze the results. The results will be summarized into a farmer-friendly bulletin that can be shared via farmer publications and other informational avenues. The results will also be used to inform the creation of an organic forage research and education agenda. This agenda will be proposed to and modified with input from other collaborating researchers and industry stakeholders across the nation. Action items relating to the agenda will be created to be utilized in future grant submissions. Due to continuing challenges related to the COVID-19 pandemic, a researcher meeting will likely be held virtually in 2022. Objective 2:Prioritize identified needs and develop research priorities and outreach that are integral in protecting and expanding our forage knowledge, especially under a changing climate through a focused researcher meeting. Due to ongoing challenges and limitations associated with the COVID-19 pandemic, an in-person researcher meeting was postponed. We anticipate meeting with the research team virtually in late spring of 2022 to develop the research and outreach agenda informed by the national survey and focus groups. Objective 3:Develop a research and outreach agenda that leads to further collaborations of the team to develop grant proposal(s) and resource materials that addresses the needs identified through this project to further forage knowledge and farm viability. Due to postponing the researcher meeting and other limitations presented by the COVID-19 pandemic, new proposals based on information generated through this project will be delayed until late 2022 or 2023. **Impacts** What was accomplished under these goals? Objective 1: Understand the critical forage knowledge gaps and resource needs of organic dairy farmers to help build resiliency and viability of those farms into the future via a national survey and focus groups. An IRB approval was received by the University of Vermont for both the Focus Groups and Survey on 15- March, 2021 (STUDY00001501). Originally, we had planned to hold the focus groups in-

person following the completion of the survey and meeting of the research team. However, due to limitations of travel and in-person meeting with regard to the COVID-19 pandemic, the focus groups were held virtually. In late April, three virtual focus group meetings were held. A total of 24 people from VT, NY, ME, VA, WI, MN, OR, and CA participated in the virtual focus groups. The participants included farmers, Extension professionals, University researchers and staff, and other industry representatives/advocates. Prior to the meetings, a short survey was sent to each participant. At the meetings, the results of the short survey were shared with participants to help prepare for and facilitated discussion. Project team members recorded and took notes during each of the focus groups and met afterwards to compile the main themes regarding research priorities, educational needs, and necessary resources to overcome organic forage production challenges. In the fall of 2021, a survey detailing current organic forage production practices, climate impacts, and needs for research, information, education, and outreach was distributed in-print to over 550 organic dairy producers across the country. In addition, dairy and forage producers received notification of the survey including a link and QR code to complete the survey online through farmer publications and email listservs (i.e. NODPA newsletter, WODPA newsletter, Organic Valley and Maple Hill Creamery producer newsletters, organization listservs, etc.). To date there have been approximately 51 and 82 responses online and in-print respectively. The survey will remain open through at least January 2022. The information generated through the focus group meetings and the national survey will be used to create a forage research and education agenda that will be proposed to other researcher and industry stakeholders. In the next reporting period we will close the survey and compile and analyze the results. The results will be summarized into a farmer-friendly bulletin that can be shared via farmer publications and other informational avenues. The results will also be used to inform the creation of an organic forage research and education agenda. This agenda will be proposed to and modified with input from other collaborating researchers and industry stakeholders across the nation. Action items relating to the agenda will be created to be utilized in future grant submissions. Due to continuing challenges related to the COVID-19 pandemic, a researcher meeting will likely be held virtually in 2022. Objective 2:Prioritize identified needs and develop research priorities and outreach that are integral in protecting and expanding our forage knowledge, especially under a changing climate through a focused researcher meeting. Identifying forage research and outreach priorities is crucial to furthering forage knowledge, education, extension, and future support. Forage needs identified through the survey and focus groups will provide the platform for developing the research and outreach agenda at the researcher meeting. The meeting will be held in a central location and will bring together agronomists, breeders, extension, research, and other industry professionals involved in forage-related research efforts to discuss the knowledge and resource gaps identified in Objective 1. During the meeting, the group will identify specific research priorities that will address the needs identified by farmers. Particular attention will be paid to research concerning forage performance under a changing climate. Due to ongoing challenges and limitations associated with the COVID-19 pandemic, an in-person researcher meeting was postponed. We anticipate meeting with the research team virtually in late spring of 2022 to develop the research and outreach agenda informed by the national survey and focus groups. Objective 3:Develop a research and outreach agenda that leads to further collaborations of the team to develop grant proposal(s) and resource materials that addresses the needs identified through this project to further forage knowledge and farm viability. This project will ultimately culminate into a forage research and outreach agenda with a planned implementation schedule. Researcher and extension teams will be formed to develop and submit proposals to OREI in 2023 as well as potential proposals to the ORG program and other USDA NIFA grant opportunities. The research agenda will be available through project PIs websites. Due to postponing the researcher meeting and other limitations presented by the COVID-19 pandemic, new proposals based on information generated through this project will be delayed. **Publications**

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Planning for Organic Seed Production Research

Accession No.	1023438
Project No.	WN.W-2020-02152
Agency	NIFA WN.W\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51300-32186
Proposal No.	2020-02152
Start Date	01 SEP 2020
Term Date	31 AUG 2021
Grant Amount	$35,105
Grant Year	2020
Investigator(s)	Zystro, J.; Colley, MI, .; McKenzie, LA, .
Performing Institution	ORGANIC SEED ALLIANCE, 210 POLK ST STE 1, PORT TOWNSEND, WASHINGTON 98368-6739

NON-TECHNICAL SUMMARY

Organic seed production and organic plant breeding are crucial to the integrity and long-term success of organic agriculture. Organic growers are required to use organic seed if commercially available, however the industry has been slow to catch up with demand in part due to a lack of information and training on optimum organic seed production practices. This planning proposal will use the following methods to assess the state of research needs around organic seed production, aiming to support the development of a full research and education proposal to the Organic Research and Education Initiative (OREI) in 2021:1. An organic seed producer and industry survey.2. A review and compilation of existing organic seed production research.3. A review of capacity and interest among researchers working in organic seed research or adjacent fields. The long-term goals of this proposal are to develop a project that will support the success of organic seed producers; increase the quality, quality, and diversity of organic seed; and ultimately ensure the long-term success of organic agriculture. This project directly addresses OREI priority four. OREI support for organic plant breeding has had a significant impact in the growth of university breeding programs releasing new organic variety releases. This project will benefit farmers and build capacity to produce commercial quantities of organically bred varieties, and will support a pipeline to amplify the work of OREI plant breeding projects.

OBJECTIVES

GoalsThe long-term goals of this proposal are to develop a project that will support the success of organic seed producers and seed companies; increase the availability of quality organic seed options for farmers; and ultimately ensure the long-term success of organic agriculture. Objectives: This planning proposal has the following objectives to assess stakeholder needs, assess the capacity of the research community, and develop a competitive proposal for an OREI organic seed production research project: A. An organic seed producer and industry survey. A survey will be distributed to certified organic seed producers across the United States to assess their seed production challenges and knowledge gaps. An additional survey will be distributed to organic seed industry representatives to identify key seed production constraints they have observed. B. A review of capacity and interest among researchers. An initial database of active and previous organic seed production research efforts will be developed. Email surveys and interviews will gauge researcher capacity, expertise and area of interest within the organic seed production field, as well as referrals to additional researchers. C. A

proposal working group. Researchers and stakeholders will be recruited to a working group based on their capacity and interest in developing a research project proposal to OREI and executing a project if funded. They will review the surveys and research review to identify priority research to include in the proposal and assist in the proposal planning and development.

APPROACH

Methods A & B. An organic seed producer and industry survey. A survey will be distributed to certified organic seed producers across the United States. We will generate the survey list from the National Organic Program\'s producer list, filtered to operations which indicate \"seed\" as one of the products produced. This list will be augmented by cross-checking against the Organic Seed Alliance contact database for additional certified organic seed producers. The survey will include demographic questions around scale, years of operation, crops produced etc., as well as questions on major production and economic challenges, priority research needs, and current methods of obtaining production information. An additional survey will be distributed to organic seed industry representatives to identify key seed production constraints they have observed. C. A review and compilation of existing organic seed production research. We will conduct a review of the existing literature and information resources available on organic seed production and on specific topics that address production challenges unique to organic management. This will both serve to ensure that the full proposal will be developed to prioritize under-researched high priority areas, while also providing an immediate resource for seed companies, producers and other researchers. D. A review of capacity and interest among researchers. An initial database of active and previous organic seed production research efforts will be developed from the research review described above. Direct email surveys and structured interviews will be conducted by OSA to identify researcher capacity and interest foci within the organic seed production field, as well as referrals to additional researcher interview candidates. This database combined with the seed producer survey will allow us to identify the areas of intersection between priority research needs and researcher programs with the capacity and interest to address those needs. E. A working group of organic seed researchers including project staff will be convened to develop a research proposal. They will review the organic seed production research needs of seed producers and the seed industry based on the surveys, review the current state of research, and review the capacities of researchers and institutions to address the priority research needs. The working group will discuss a draft framework for a project, and create a timeline and task list for project participants to assist in developing a project proposal. OSA staff will lead and coordinate the project and OREI proposal development in conjunction with working group members and other stakeholders. The proposal will include elements of seed production research such as comparative studies on seed yields under differing production practices, assessments of seed yield and quality across crops and regions, educational activities and products, and economic analysis, based on the needs, gaps, resources, and priorities determined through the process described above. Evaluation The results of the producer and industry survey will be analyzed using both quantitative and qualitative methods. Quantitative analysis will be done using the R software package (R Core Team, 2018) to calculate response means and errors. Interview data will be coded and qualitative textual analysis will be done to identify salient common themes in the responses to open ended questions. Salient themes and patterns will be defined, named, and analyzed. The success of the planning process will be assessed based on the following milestones: 1) Strong responses to the producer and industry surveys with needs clearly identified, 2) Clear identification of existing resources from the research review and researcher capacity survey, and 3) a strong proposal submitted to the 2022 OREI RFP. **Progress** 09/01/20 to 08/31/22 **Outputs** Target Audience:The target audiences for this project were organic seed producers, organic seed companies, and researchers working on organic seed and organic plant breeding efforts.
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 resultsof this project, including the organic seed producer surveys, the organic seed company surveys, the organic seed researcher surveys, the seed producer interviews, and the research funding analysishave been incorporated into the State of Organic Seed Report and theState of Organic Seed interactive data explorer. The results were publicized through Organic Seed Alliance\'s contact databaseand through partnering organizations including the Organic Farming Research Foundation.In addition, these results have been shared during presentations at agriculture conferences and atNational Organic Program meeting. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? Organic Seed Producer and Seed Company Surveys We conducted a formal survey of organic seed growers and organic seed suppliers. The purpose was to better assess the challenges and opportunities in growing the organic seed industry, understand what they perceive as their \"seed networks,\" and identify research priorities. We heard from 88 seed producers and 39 companies that range in scale and size. We gathered seed producer contact information from the NOP\'s INTEGRITY database. The database was queried for certified organic growers with organic products (June 2020) and organic crops (July 2020). We reviewed the contacts to identify growers with \"seed\" in their crops or products and manually coded to categorize crop and

product categories. These data were combined with two lists from OSA. One was a list of contacts that likely contained seed producers and another was an expertly generated list of seed company contacts. These lists were compared and redundancies removed, resulting in a list with 416 seed producers and 90 seed companies. Surveys were developed during the summer and fall of 2020, with feedback from a sample of pilot survey-takers in each group. The surveys included questions that asked respondents to describe their operation, the challenges they face in their role, the crops they work with and breeding priorities, the people or organizations they use as resources in their networks, their personal definition of \"resilience\", and their perceptions on climate change and intellectual property rights. Seed producers and seed companies had largely similar surveys, though some differences were made to account for the different roles of these stakeholders. Surveys were hosted on the Qualtrics survey platform and distributed over email, with individual links for each respondent. Producer surveys were distributed between October and December 2020 and company surveys were distributed between January and March 2021. Each potential respondent was sent an initial email invitation with three reminders, spaced out every two to three weeks. Phone calls were randomly made to producers for the third reminder to increase response rates. Of the 416 seed producers contacted there were 88 full responses from organic seed producers for a response rate of 21 percent. Of the 90 seed companies contacted there were 39 full responses for a response rate of 43 percent. Together there were 127 responses out of 506 seed producers and companies, for a 25 percent response rate. Regionally, the response rate was 22 percent from the North Central region (20 of 92), 23 percent from the Western region (67 of 293), 29 percent from the Southern region (10 of 35), 32 percent from the Northeast region (17 of 54), 20 percent from Canada (3 of 15), and 20 percent from those with unidentifiable locations (3 of 14). We combined the seed producer and companies surveys for analysis. Respondents were asked about their operation and challenges and perceptions on key issues. We summarized responses using R Statistical Software. We also read the individual definitions of resilience (an open-ended question) and manually coded them for major themes using NVivo qualitative coding software. Responses about seed producer and companies networks were manually cleaned and used to create a database of all seed stakeholders, which allowed for the mapping and analysis of the organic seed network. Organic Seed Researcher Survey We conducted a formal survey of organic seed researchers. The purpose was to better understand the successes, challenges, and opportunities for organic seed research, as well as researchers\' perspectives on key issues. We heard from 51 researchers, 43 from universities and 8 from organizations. Researchers were identified based on their receipt of organic research grants, participation in OSA research programs, recent publications on organic seed, and through a snowballing survey method. Thirty-four recipients of organic research grants between 2016 and 2020 were identified through online searches. The grants included in the online searchers included SARE, OERI, NIFA, OFRF, and CERES. Nine researchers were identified based on past research with OSA. Furthermore, Web of Science was used to identify academic papers published between 2016 and 2020 that used variations on key words relating to seed, breeding, and organic production, which identified five more researchers. And we asked these survey respondents to identify other researchers they collaborate with on these projects, adding another 29 researchers. In total, 77 researchers were identified, 65 from universities and 12 from governmental and non-governmental organizations. Of the 77 researchers contacted there were 51 full responses (8 from organizations and 43 from universities) for a response rate of 66 percent. Regionally, the response rate was 70 percent from the North Central region (16 of 23), 52 percent from the Western region (11 of 21), 70 percent from the Southern region (14 of 20), and 78 percent from the Northeast region (17 of 53). Surveys were developed during the summer of 2021, with feedback from a sample of pilot survey-takers in each group. The surveys included questions that asked respondents to describe their most recent organic-related research project, the expertise they have in their role, the crops they work with and breeding priorities, the people or organizations they use as resources in their networks, their personal definition of \"resilience,\" and their perceptions on climate change and intellectual property rights. Surveys were modeled after the organic seed producer and company surveys, but adjusted for relevance to the respondents. Surveys were hosted on the Qualtrics survey platform and distributed over email, with individual links for each respondent. Researcher surveys were distributed between September and December 2021. Each potential respondent was sent an initial email invitation with three reminders, spaced out every two to three weeks. Proposal working group Researchers and stakeholders were recruited to an OREI research proposal working group based on their capacity and interest in developing a research project proposal to OREI and executing a project if funded. Theproposal, titled \"OSPREY: Organic Seed Production Resources on Equipment and Yield\" wasa research proposal to develop integrated, regional, research-based commercial organic seed production resources. Based on the critical stakeholder needs identified through the surveys and interviews, this proposal soughtto do the following: * Conduct multi-regional replicated seed yield trials across a range of crops * Conduct seed production experiments comparing yields and quality based on management factors such as planting density. * Coordinate large-scale crowd-sourced seed yield trials. * Conduct comparative seed equipment testing. * Compile information on seed disease. * Develop economic decisions tools to calculate break-even price points based on seed yield data and scale; and to calculate payback periods to compare seed equipment based on the equipment testing. * Compile the results into both interactive and printable resources. The proposal was submitted to OREI

as part of the 2022 funding cycle. While it was not selected for funding, the reviewers felt that it\"will address a clearly defined problem and is a good fit for the program.\" The project team is committed to strengthen the proposal, address the reviewers\' concerns, and re-submit during the 2023 funding cycle. **Publications** - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Hubbard, K., J. Zystro, and L. Wood. 2022. A Snapshot of State of Organic Seed, 2022. In Lordon, M. (ed). Organic Seed Growers Conference Proceedings. Organic Seed Alliance, Port Townsend, WA. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Wood, L. 2022. Assessing the resilience of the organic seed system: A network perspective. In Lordon, M. (ed). Organic Seed Growers Conference Proceedings. Organic Seed Alliance, Port Townsend, WA. - Type: Websites Status: Published Year Published: 2022 Citation: Hubbard, K., J. Zystro, and L. Wood. 2022. State of Organic Seed, 2022. Retrieved December 20, 2022, from https://stateoforganicseed.org/state-of-organic-seed-2022/ **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience:During this reporting period, we conducted surveys and interviews with organic seed producers, organic seed companies, and researchers working on organic seed and organic plant breeding efforts. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals?Researchers and stakeholders have been recruited to an OREI research proposal working group based on their capacity and interest in developing a research project proposal to OREI and executing a project if funded. A proposal is in development for the 2022 OREI RFA. This proposal, titled \"OSPREY:Organic Seed Production Resources on Equipment and Yield\" is a research proposal to develop integrated, regional, research-based commercial organic seed production resources. Based on the critical stakeholder needs identified through the surveys and interviews, this proposal seeks to do the following: * Conduct multi-regional replicated seed yield trials across a range of crops * Conduct seed production experiments comparing yields and quality based on management factors such as planting density. * Coordinate large-scale crowd-sourced seed yield trials. * Conduct comparative seed equipment testing. * Compile information on seed disease. * Develop economic decisions tools to calculate break-even price points based on seed yield data and scale; and to calculate payback periods to compare seed equipment based on the equipment testing. * Compile the results into both interactive and printable resources. **Impacts** What was accomplished under these goals? Organic Seed Producer and Seed Company Surveys We conducted a formal survey of organic seed growers and organic seed suppliers. The purpose was to better assess the challenges and opportunities in growing the organic seed industry, understand what they perceive as their \"seed networks,\" and identify research priorities. We heard from 88 seed producers and 39 companies that range in scale and size. We gathered seed producer contact information from the NOP's INTEGRITY database. The database was queried for certified organic growers with organic products (June 2020) and organic crops (July 2020). We reviewed the contacts to identify growers with \"seed\" in their crops or products and manually coded to categorize crop and product categories. These data were combined with two lists from OSA. One was a list of contacts that likely contained seed producers and another was an expertly generated list of seed company contacts. These lists were compared and redundancies removed, resulting in a list with 416 seed producers and 90 seed companies. Surveys were developed during the summer and fall of 2020, with feedback from a sample of pilot survey-takers in each group. The surveys included questions that asked respondents to describe their operation, the challenges they face in their role, the crops they work with and breeding priorities, the people or organizations they use as resources in their networks, their personal definition of \"resilience\", and their perceptions on climate change and intellectual property rights. Seed producers and seed companies had largely similar surveys, though some differences were made to account for the different roles of these stakeholders. Surveys were hosted on the Qualtrics survey platform and distributed over email, with individual links for each respondent. Producer surveys were distributed between October and December 2020 and company surveys were distributed between January and March 2021. Each potential respondent was sent an initial email invitation with three reminders, spaced out every two to three weeks. Phone calls were randomly made to producers for the third reminder to increase response rates. Of the 416 seed producers contacted there were 88 full responses from organic seed producers for a response rate of 21 percent. Of the 90 seed companies contacted there were 39 full responses for a response rate of 43 percent. Together there were 127 responses out of 506 seed producers and companies, for a 25 percent response rate. Regionally, the response rate was 22 percent from the North Central region (20 of 92), 23 percent from the Western region (67 of 293), 29 percent from the Southern region (10 of 35), 32 percent from the Northeast region (17 of 54), 20 percent from Canada (3 of 15), and 20 percent from those with unidentifiable locations (3 of 14). We combined the seed producer and companies surveys for analysis. Respondents were asked about their operation and challenges and perceptions on key issues. We summarized responses using R Statistical Software. We also read the individual definitions of resilience (an open-ended question) and manually coded them for major themes using NVivo qualitative coding software. Responses about seed producer and companies networks were manually cleaned and used to create a database of all seed stakeholders, which allowed for the mapping and analysis of the organic seed network. Organic Seed Researcher Survey We conducted a formal survey of organic seed researchers. The purpose was

to better understand the successes, challenges, and opportunities for organic seed research, as well as researchers' perspectives on key issues. We heard from 51 researchers, 43 from universities and 8 from organizations. Researchers were identified based on their receipt of organic research grants, participation in OSA research programs, recent publications on organic seed, and through a snowballing survey method. Thirty-four recipients of organic research grants between 2016 and 2020 were identified through online searches. The grants included in the online searchers included SARE, OERI, NIFA, OFRF, and CERES. Nine researchers were identified based on past research with OSA. Furthermore, Web of Science was used to identify academic papers published between 2016 and 2020 that used variations on key words relating to seed, breeding, and organic production, which identified five more researchers. And we asked these survey respondents to identify other researchers they collaborate with on these projects, adding another 29 researchers. In total, 77 researchers were identified, 65 from universities and 12 from governmental and non-governmental organizations. Of the 77 researchers contacted there were 51 full responses (8 from organizations and 43 from universities) for a response rate of 66 percent. Regionally, the response rate was 70 percent from the North Central region (16 of 23), 52 percent from the Western region (11 of 21), 70 percent from the Southern region (14 of 20), and 78 percent from the Northeast region (17 of 53). Surveys were developed during the summer of 2021, with feedback from a sample of pilot survey-takers in each group. The surveys included questions that asked respondents to describe their most recent organic-related research project, the expertise they have in their role, the crops they work with and breeding priorities, the people or organizations they use as resources in their networks, their personal definition of \"resilience,\" and their perceptions on climate change and intellectual property rights. Surveys were modeled after the organic seed producer and company surveys, but adjusted for relevance to the respondents. Surveys were hosted on the Qualtrics survey platform and distributed over email, with individual links for each respondent. Researcher surveys were distributed between September and December 2021. Each potential respondent was sent an initial email invitation with three reminders, spaced out every two to three weeks. **Publications**

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Connecting Community to Strengthen Organic Seed Breeding and Research

Accession No.	1023442
Project No.	WN.W-2020-02126
Agency	NIFA WN.W\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51300-32187
Proposal No.	2020-02126
Start Date	01 SEP 2020
Term Date	31 AUG 2021
Grant Amount	$41,910
Grant Year	2020
Investigator(s)	Loriz, C.; Moore, VI, .
Performing Institution	ORGANIC SEED ALLIANCE, 210 POLK ST STE 1, PORT TOWNSEND, WASHINGTON 98368-6739

NON-TECHNICAL SUMMARY

The Student Organic Seed Symposium (SOSS) is an annual research and networking event held by and for graduate students working in organic plant breeding and seed systems. Approaching its tenth year providing networking and professional development for the next generation of organic seed academics and professionals, this project seeks to extend the reach of SOSS beyond the intimate gathering that takes place each August. In 2021, SOSS will be held over three days in Madison, WI and will include presentations by thought leaders in organic breeding and seed systems, discussions, career panels, and an outreach event open to the general public and organic community. Students will have the opportunity to present their research, including sharing breeding material through demonstration plots. This project will increase the impact of SOSS through outreach including publicly available webinars, through travel grants for graduate students, and through networking events aimed at recruiting a more diverse pool of SOSS participants and increasing the visibility of organic seed research across the wider scientific community. Impacts of the project will be documented through event attendance, reports from travel grant recipients, a feedback sesssion at the symposium, and a post-symposium survey.

OBJECTIVES

The long-term goal of this project is to build and maintain a network of stakeholders including students, academics, farmers, and seed professionals passionate about research and the advancement of organic seed systems. This network promotes and develops breeding priorities, techniques, and approaches within the organic seed sector, and serves as a channel to disseminate research and innovations that lead to broader access to improved varieties. Our network includes professionals across various agricultural sciences in addition to breeders, including agroecologists and rural sociologists. We have a strong record of supporting graduate student professional development through access to leading scholars, industry pioneers, and critical stakeholders in organic seed systems. We recognize the importance of connecting graduate students working in organic seed systems to wider academic and professional networks for students\' professional development and for wider visibility of organic seed and breeding research. To this end, in addition to the annual SOSS, we will host sessions at larger academic conferences. Even as the need for organic seed grows, few university programs

focus on organic crop improvement and students focused on organic plant breeding and seed research often lack a supportive community for their work. This project aims to advance organic plant breeding and seed system research to ensure a robust and sustainable future for organic agriculture through support of SOSS and other professional development opportunities for graduate students. The specific objectives of the project include: Promoting networking among graduate students, and academic and industry professionals within the organic seed sector to facilitate post-graduation job opportunities for graduate students in the organic seed sector; Communicating the latest organic plant breeding research and seed-based initiatives to SOSS participants and the broader organic seed community; Initiating science-based discussions to identify organic breeding priorities and evaluate techniques; Connecting organic seed and plant breeding research to broader scientific communities

APPROACH

A. STUDENT ORGANIC SEED SYMPOSIUMDay 1: Attending SOSS participants will meet for the commencement of the annual symposium. The welcoming address themed \'The Need for Organic Seed\' and statements will be followed by a joint dinner. The evening will conclude with a \"Free the Seed\" seed swap and opportunity for the mingling and networking of all participants.Day 2: A leading keynote speaker will highlight strengthening the organic seed systems with a \'Participatory models and tomorrow\' themed address. Several sessions, including educational workshops, career panels, and science-based discussions designed to promote interaction and foster mentorship between attendees are planned. To enhance the professional development of graduate student participants, a \'Think Tank\' brainstorming session will promote discussion on needed background, potential training gaps, and concerns of graduate students as they transition into professional fields. These sessions can also foster graduate curriculum development and interaction between student participants and other OREI proposed projects focused on organic crop breeding and seed systems. Additional networking opportunities will include student poster presentations and a garden walk at the Allen Centennial Gardens showcasing Society members\' crop research and released varieties bred for organic production. The evening will culminate with a public Science Cafe event, presenting an open panel discussion of organic industry leaders in a casual environment to provide dissemination of knowledge and discussion of relevant issues with the general public and organic community. Day 3: Mirroring the structure of many professional meetings, the focus will be research and professional presentations given by attendees, selected and accepted from submitted abstracts. Organic researchers and professionals spanning diverse fields will disseminate research in cohesive themed sessions, including \'Intellectual property in organic seed systems\' and \'Decentralized selection and adaptability\', which will be followed by roundtable discussions. The day will conclude with a keynote address \'Breeding better breeders\' to provide audience motivation to continue the valued and necessary work required to ensure a successful future for organic agriculture.B. GRADUATE STUDENT TRAVEL AWARDSCompetitive travel awards will be provided to graduate students researching topics in organic seed and plant breeding in order to connect with the broader networks of researchers in agriculture and the biological sciences. These awards will be advertised widely to graduate students through the existing SOSS and Organic Seed Alliance contact databases, through social media and through outreach to agricultural and biological science departments.The application for the travel awards will require a description of the student\'s research, a plan for how the student will be sharing their research at the conference, and a budget with estimated expenses and other sources of travel support. This award process will be used to provide support for student travel to SOSS, but also to larger academic and professional conferences.Students receiving awards will be required to write a brief post at the event that can be shared to SOSS social media and will write a brief report on their experience after the conference.C. NETWORKING EVENTSIn addition to providing travel awards to larger academic and professional conferences, we will strategically plan networking events at these conferences. These sessions will serve three primary functions: (1) as an opportunity for SOSS alumni to connect with each other beyond the annual conference and build collaborations within the SOSS network, (2) to increase visibility of SOSS and organic plant breeding/seed systems research and recruit a more diverse group of participants for future SOSS events, and (3) to connect SOSS alumni with academics and professionals who have not previously been engaged with SOSS or organic plant breeding/seed systems research but who have been strategically invited due to their relevant subject matter expertise. These networking events will be co-organized by SOSS alumni in coordination with conference organizers. Likely conferences at which these networking events will take place include the National Association of Plant Breeding (NAPB) annual meeting, the American Society for Horticultural Science conference, and the Tri-Societies (Agronomy, Crop Science, and Soil Science societies) annual meeting. Progress 09/01/20 to 08/31/22 Outputs Target Audience: The target audience of this project consisted of graduate students conducting research in organic plant breeding and seed systems with a secondary audience of seed professionals to serve as mentors to the students and/or connect their research to on-farm impacts. The 2022 Student Organic Seed Symposium SOSS was organized by graduate students (and recent graduates) serving on a planning committee. Stakeholder engagement through student organizing, discussion, and surveys informed the development of this project. Due to the COVID pandemic, engagement with the target audience

since the last SOSS event, held in Madison, WI in 2019, has been primarily conducted through virtual events and digital communications. These communications included social media and email outreach to Society of Organic Seed Professionals membership; researchers, students and program participants in the Organic Seed Alliance contact database, university listservs and through networks of partnering organizations. Networking activities and outreach were also conducted during the annual meetings or conferences of the National Association of Plant Breeders, Northern Organic Farmers Association - New York and Tri-Societies. Engagement with new students was challenging during the pandemic and initial registrations for the first in-person symposium in three years were modest. As the event drew closer, outreach efforts intensified, including an effort to encourage participation of local agricultural students and those attending Historically Black Colleges and Universities as well as local food systems leaders to support student education on the theme of \"Small-scale agriculture: sowing sustainable local food systems.\" Total registration for the event numbered 55, with seven local university researchers also attending without registering. Twenty-four of the registered attendees were students; participant survey data indicated that nearly half of the participants (45%) identified as Latino, Black, Asian, Indigenous/Pacific Islander or Middle Eastern. The symposium was described by a seed company owner and Black farming mentor as one of the most diverse she has ever attended. Participants were also invited to present their own research. These included research presentations by six West Virginia University professors and 13 graduate students, post-docs or recent graduates. Changes/Problems:The most significant challenge for this project was the COVID pandemic, which disrupted student activities and engagement as well as capacity ahead of this event. The project leaders were grateful for the no cost extension from NIFA that allowed support of an event in 2022 instead of 2021. While we were able to deliver the event in 2022, we were compelled to honor a commitment to hold the next SOSS event at West Virginia University. The most recent SOSS event prior to 2022 was held at University of Wisconsin-Madison in 2019; repeating the symposium in the same location would not meet our goal of broadening organic stakeholder participation and expanding networking into underserved regions. While the venue changed from the original proposal, all goals were met and many were exceded due to the vigorous involvement of regional food systems leaders from the Southeast. What opportunities for training and professional development has the project provided? One of the most important goals of SOSS is to provide professional development opportunities for attendees. The majority of classroom presentations included training on breeding and/or seed saving skills, specifically for varieties that have been regionally adapted to the Southeast. To increase connection between attendees, the SOSS leaders organized a \"Speed Mentoring\" session where graduate students and young seed practitioners had five minutes to hear opportunities and advice from professionals in the organic seed sector. This was one of attendees'; favorite sessions. Attendees noted the following favorite activities on their survey responses: \"The speed dating mentorship activity felt like we were actually giving practical advice that people could use immediately.\" \"The mentorship activity was probably my favorite activity overall. I felt like I connected with people more than in other activities.\" \"Speed mentoring activity - it let me talk to some folks I hadn';t met yet.\" Seed saving and plant breeding skills and resources were also expanded during the symposium through knowledge sharing, how-to videos with expert Q&A, and hands-on activities at the WVU Research Farm. Approximately 73% of respondents said that their knowledge of growing seed and plant breeding increased some what or very much as a result of the symposium and 91% received access to new resources. When asked if they had identified next steps in advancing their professional work, 100% responded positively. One attendee commented that the biggest takeaway from the symposium was: \"That seed saving and breeding are accessible to everyone, farmers and academics alike, if we have the right knowledge/tools.\" \"It takes all of us (farmers, researchers, chefs, storytellers) to further our aims of creating genetic diversity and adapting to climate change.\" \"Creating a network of seed growers (particularly in the South) is something to really focus on in order to mentor a cohort of seed savers.\" How have the results been disseminated to communities of interest? Final production of symposium papers is in process and will be shared through OSA's contact database, published on the SOSS and OSA websites, and posted on the Organic Seed Commons networking platform SOSS event page to encourage ongoing conversations about the topics presented at the symposium. The video recording of \"Appalachian Food Stories with Mike Costello\" is posted on OSA's YouTube channel and has been viewed 22 times. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? The project met the broadest goal of cultivating and engaging a network of stakeholders passionate about research and the advancement of organic seed systems. This is the mission of the student symposium each year and at each venue in which it is hosted, be it Madison, WI or the 2022 location of Morgantown, WV. Participant feedback confirms this success. Survey responses were completed by 20% of registrants, more than half of whom identified as graduate students, plant breeders or university researchers. Overall, attendees rated the conference positively; on a scale of 1 (poor) to 5 (excellent), the symposium received a 4.1 rating. Specific objectives were also met as described below. Goal 1. Promoting networking among graduate students, and academic and industry professionals within the organic seed sector to facilitate post-graduation job opportunities for graduate students in the organic seed sector. SOSS 2022 provided a high level of meaningful networking between graduate students and practitioners in the organic seed sector. In addition to dedicated networking activities, the small size of the cohort and shared social times around meals and

travelling to field trips provided ample oppotunities to network. When asked if the symposium \"expanded or enriched your peer relationships and networks,\" attendees overwhelming responded \"Very Much\" (versus \"Somewhat\" or \"Not much\").Several respondents noted that networking was one of the most valuable components of the symposium. One attendee described what they will take away from the event: \"My biggest takeaway was the networking that I was able to do. It feels good to start connecting the dots between what breeders are doing and how that plays out for farmers in the field. Often the breeding work in universities is geared towards large scale producers, so it was nice to have small farmers represented.\" The greatest opportunities for advancement came from graduate student attendees engaging with the WVU plant breeding faculty and with several seed company representatives. Follow up surveys (six or 12 months out from the event) are needed to determine whether research and job opportunities arose from this engagement. Goal 2: Communicating the latest organic plant breeding research and seed-based initiatives to SOSS participants and the broader organic seed community SOSS 2022 accomplished this goal and was particularly successful in communicating organic plant breeding research to non-academic seed practitioners. The effort to register food system leaders from the southeast brought together researchers and small-scale seed growers in numbers and in settings that encouraged meaningful communications and connection. Presentations of plant breeding and variety development research by six WVU Agriculture Department faculty and 13 graduate students, post docs and professional researchers from other universities provided up-to-date results and insights on the latest research. Field presentations included discussion of varieties from other university programs grown out for demonstration at the WVU Research Farm. Crop research focused on wheat, barley, dry beans, sweet corn, dry corn, tomatoes and hemp. The academic research was complemented by practical experiences from regional seed initiatives focusing on southern peas, okra, collards and culturally significant varieties of corn. Goal3. Initiating science-based discussions to identify organic breeding priorities and evaluate techniques The small size of the participant cohort provided attendees with opportunities to ask specific questions about the organic plant breeding research presented as well as the seed saving, variety improvement and conservation practices of regional practitioners. Presentations of trials and on-farm research delivered in the field, by WVU students and professors as well as six visiting graduate students and post docs who provided seed to the WVU research farm last spring for demonstration plots, provided hands-on science-based discussions, identification of pests and genetic expression. Open-ended survey responses to what attendees found most valuable about the symposium address this accomplishment: \"Talking with people after talks. Especially people I hadn't met before. And the tomato geneticists at the WVU Farm.\" \"I LOVED seeing community seed workers and academics interact and nerd out about seeds - especially outside of conference sessions. It felt like one community for the most part. Younger plant breeders are aware of a need for biodiversity, which gives me hope for the future.\" Goal 4. Connecting organic seed and plant breeding research to broader scientific communities This goal of the event was fulfilled by engaging with academic and community leaders who do not work directly in organic crop breeding. Though presentations and field activities, attendees engaged experts on pasture establishment, fir tree breeding, soil biome health, and trellising techniques. Attendees also engaged with graduate students working in remote sensing applications of genomic wheat research as well as the materials engineering qualities of okra. One goal of the original project was to support graduate student attendance at other national conferences featuring broader scientific scopes. The COVID pandemic limited these opportunities to virtual attendance, which included student organizing activities around annual meetings of the National Association of Plant Breeders, Northern Organic Farmers Association - New York and Tri-Societies. **Publications** - Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2023 Citation: Loriz, C. (editor). 2022. Student Organic Seed Symposium Papers and Presentations. July 27 - 31, 2022, Morgantown, WV. Organic Seed Alliance, Port Townsend, WA. 15 pp. - Type: Other Status: Awaiting Publication Year Published: 2022 Citation: Mike Costello, Interactive Appalachian Food Stories Workshop, Lost Creek Farm. Video available on the Organic Seed Alliance YouTube channel. <https://www.youtube.com/channel/UCIBRURAK4RGnmpD843FZSDg>. **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience: Nothing Reported Changes/Problems: Due to the COVID-19 pandemic, the Student Organic Seed Symposium originally proposed for the summer of 2021 is now taking place in the summer of 2022. All related project activities have similarly been moved back one year. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals? The Student Organic Seed Symposium will be held July 27-30 in Morgantown, West Virginia. Several sessions, including research presentations, educational workshops, career panels, and science-based discussions designed to promote interaction and foster mentorship between attendees are planned. Additional networking opportunities will include student poster presentations and a field tour showcasing Society members' crop research and released varieties bred for organic production. To gauge the impact of the symposium, as well as assess specific aspects including networking, planned activities, and speaker selection, conference evaluations and data will be collected through web-based survey questions and testimonial responses. Competitive travel awards will be provided to graduate students researching topics in organic seed and plant breeding in order to connect with the broader networks of researchers in agriculture and

the biological sciences. These awards will be advertised widely to graduate students through the existing SOSS and Organic Seed Alliance contact databases, through social media and through outreach to agricultural and biological science departments. Students receiving awards will be required to write a brief post at the event that can be shared to SOSS social media and will write a brief report on their experience after the conference. Networking events for organic seed researchers and students will be planned at key plant sciences conferences, and graduate student travel awarded will be provided. These networking events will be co-organized by SOSS alumni in coordination with conference organizers. Likely conferences at which these networking events will take place include the National Association of Plant Breeding (NAPB) annual meeting, the American Society for Horticultural Science conference, and the Tri-Societies (Agronomy, Crop Science, and Soil Science societies) annual meeting. **Impacts** What was accomplished under these goals? Due to the COVID-19 pandemic, the timeline for the Student Organic Seed Symposium and associated project activites were moved back one year, to 2022. **Publications**

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Assessment of Inadvertent Chemical Contamination of Organic Crops

Accession No.	1023703
Project No.	WNP02204
Agency	NIFA WN.P\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51300-32261
Proposal No.	2020-02235
Start Date	01 SEP 2020
Term Date	31 AUG 2021
Grant Amount	$50,000
Grant Year	2020
Investigator(s)	Goldberger, J.; Dyer, WI.; Maxwell, BR.; Hassanein, NE.; O\'Donnell, MI.; Shade, JE.; Sciligo, AM.; Delbridge, TI.; Zhou, XI.; Merrigan, KA.
Performing Institution	WASHINGTON STATE UNIVERSITY, 240 FRENCH ADMINISTRATION BLDG, PULLMAN, WASHINGTON 99164-0001

NON-TECHNICAL SUMMARY

Unintentional pesticide contamination in organic crops has been flagged as a major challenge by the organic sector, across the supply chain. Contamination can have a disproportionate impact on organic farmers because organic stakeholders along the entire supply chain are burdened with the cost of testing, and experience losses when tests are positive. While the organic community has identified this as a critical topic for investigation, few data have been collected synthesizing the experiences and research needs of the organic community. This planning grant will fill a major knowledge gap by bringing together organic stakeholders and scientists to determine the crops that are most heavily impacted by contamination, conventional pesticides that the organic industry has detected on its crops, losses that organic farmers and industry members have experienced, strategies that organic farmers have undertaken to reduce pesticide drift, and research needs for identifying vectors and preventing contamination. This will largely be accomplished through a national needs assessment combined with a meeting of farmers and researchers to discuss the greatest needs discovered in the national survey. This information will aid the development of a large-scale, interdisciplinary research proposal. This proposal will evaluate and characterize the experiences, challenges, and true costs associated with inadvertent chemical contamination, and identify the research needs of organic producers and other stakeholders along the organic supply chain. The project will work with stakeholders to identify the study regions and research questions that need to be prioritized and develop a multi-regional research proposal to submit in the following year. The full research proposal will present a research plan to reduce contamination events and address burdens associated with contamination, such as the costs associated with testing for contamination and positive test result mitigation efforts such as the cleanup of contaminated soils.The long-term goal of this project is to provide organic growers and industry members with feasible methods to manage pesticide contamination. The specific objectives of this proposal are to: 1) gather information on current losses, specific pesticide residues, and techniques utilized by organic growers and industry members to minimize contamination; 2) assess the target audience\'s research priorities for reducing pesticide contamination; 3) determine research, outreach, and education needs for developing and delivering a comprehensive plan to control pesticide contamination in organic crops across the supply chain.

OBJECTIVES

Our long-term goal is to provide organic farmers and industry members with economical and feasible methods to manage inadvertent pesticide contamination on their crops. The specific objectives of this proposal are to: 1) Gather information on current losses, specific pesticide residues, and techniques being utilized by organic farmers and industry members to minimize contamination; 2) Assess the target audience\'s priorities related to research on reducing pesticide contamination; 3) Determine research, outreach, and education needs for developing and delivering a comprehensive plan for controlling pesticide contamination in organic crops across the supply chain; 4) Develop a full multi-regional OREI research proposal to be submitted in 2021.

APPROACH

Efforts: This planning grant will conduct a needs assessment of organic farmers faced with chemical contamination of their crops. The study will quantify and characterize the current challenges and needs of farmers by using a survey and direct dialogue with focus groups and interviews with stakeholders. The project will culminate in a white paper that will be shared with the organic community so that feedback can be offered and incorporated into the development of a full research proposal. To help guide the proposed project and extend our reach throughout the U.S. organic community we have assembled a multi-disciplinary, multi-institutional, and multi-state advisory committee. The needs assessment will be conducted in five tasks, listed below. The target audience includes a variety of stakeholders: farmers, processors, certifiers and research experts working with contamination in organic crops.Task 1: Convene the Advisory Committee. The Advisory Committee will help with the organization and implementation of subsequent stages through video conferences, conference calls, and email communications.Task 2: Develop and implement a national survey and discussion groups. The project director, Dr. Goldberger, with input from the research team and Advisory Committee members, will develop a web-based survey to gather data from organic producers and buyers using the Tailored Design Method to ensure a high response rate. We will publicize the survey via listservs, organic farmer associations, conferences, newsletters, and organic agriculture organizations/farmer groups. Because not all members of the organic community have access to online resources, we will also pass out hard copies of our survey with addressed, stamped envelopes at grower conferences such as Ecofarm and MOSES, and work with cooperatives and grower groups who will be able to connect us with organic farmers who do not use email. We will also host listening sessions at national and regional grower meetings.Task 3: Host a focused in-person meeting to develop research priorities and plan for full research proposal. Stakeholders and advisory committee members will meet for a 2-day workshop. The overall goal of the workshop will be to develop an integrative research plan to submit as a full OREI proposal in 2021. To achieve this, we have four main objectives: 1) Present research priorities identified by the national survey and all stakeholders groups represented by meeting attendees to share their views, 2) Narrow the focus to a small handful of questions with testable hypotheses for which a full research project could be developed by a core research team, 3) Form appropriate academic sub-teams who could study the identified research questions, and 4) Obtain commitment from academic team members to lead the writing and submission of a full proposal. Task 4: Communicate workshop findings to the organic community: A final report will be generated as a white paper and distributed to all the stakeholders who participated in the survey and/or workshop. This report will also be publicized through similar channels as the survey to allow others to comment before the full proposal is developed. The Organic Center will also build a webpage to communicate updates about the project to the organic community.Task 5: Core research team will meet via webinar and/or conference call to write and submit a full OREI multi-regional proposal submission. **Progress** 09/01/20 to 08/31/22 **Outputs** Target Audience:The target audience for our project includes organic farmers; organic certifiers; food handlers, processors, manufacturers, and distributors; general public (consumers), academic researchers, and policy makers. Changes/Problems:Challenges to the completion of Objective #4 (developing a full proposal for the 2023 OREI funding cycle):While significant progress was made to narrow down research priorities and future project aims/objectives, the challenge is that the issue of inadvertent pesticide contamination is a very wide-reaching problem. According to our needs assessment, this problem doesn't seem to be sector or regionally specific and requires a truly interdisciplinary approach to not only comprehensively assess the costs/extentof the problem of contamination, but to develop strategies to alleviate those costs. After nearly two years of planning, this work still remains absent of a lead PI who is willing and able to lead a full OREI proposal and research project. The study approach that the current planning team has landed on will require a strong social science component and economic analysis with less of a field study component. It's unclear whether the current OREI priorities would accommodate this study design. Additionally, while most participating planning team members are extremely interested in and passionate about this work, those who have some capacity to lead a proposal do not currently have the administrative support at their universities to submit a full proposal or their location does not match up with the study location, making it hard to manage staff and fieldwork in the study regions.To overcome these challenges, next steps require broadening the search of academic researchers to find

those who have the expertise to conduct this work in the most impactful study regions, and who have the capacity and infrastructure to submit a grant proposal and manage a largely interdisciplinary team across multiple institutions. Lastly,while the OREI funding limit is a generous amount of money, it is not nearly enough to meet the needs of a fully comprehensive study to address all the research objectives that this team has identified. Therefore, only bits and pieces can be accomplished, and it has been a challenge to determine which pieces can be removed form the project to still produce relevant and impactful outcomes. What opportunities for training and professional development has the project provided?Various academics have been exposed to different disciplinary perspectives and some have learned more about the organic regulations and the organic experience when it comes to inadvertent pesticide contamination. How have the results been disseminated to communities of interest?Outreach activities included the hosting of planning meetings where stakeholders across the supply chain were invited via The Organic Center's and Organic Trade Association's networks, and the networks of all involved Co-PIs and advisory board.Team members from this project also attended meetings hosted by other research teams (e.g., Ohio State University and IFOAM pesticide contamination working group) where our project and survey results were summarized and shared. This lead to the fostering of new collaborations. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? Objective 1:We developed a survey instrument (\"Inadvertent Pesticide Contamination Survey: A Survey of Certified Organic Producers, Processors, and Handlers\") in September-October 2020.The survey included questions about the extent of inadvertent pesticide contamination, mitigation strategies (and their effectiveness), research/outreach needs, and opinions about testing, impacts, consumer behavior, and other topics. Objective 2:The national survey included questions developed to gather information related to research priorities.The data from these questions were presented at a virtual, national planning summit hosted by The Organic Center to assess whether other stakeholders agreed with survey results, and offered the opportunity to add additional perspectives.While the organic community (in addition to survey respondents) agreed largely with the survey results, the strongest need identified was the consolidation of results of all available pesticide testing data and a comprehensive examination of economic and non-economic costs of positive test results from across the nation. Objective 3:The national survey included questions developed to gather information related to outreach and education priorities.The data from these questions were presented at a virtual, national planning summit hosted by The Organic Center to assess whether other stakeholder agreed with survey results, and offered the opportunity to add additional perspectives. In addition to the survey results the additional planning meetings revealed that there was a strong need to increase dialogue between organic farmers and their neighbors. Field watch has hosted moderating dinners in the past that were very successful in educating pesticide applicators and conventional neighbors about the rules of organic and the challenge and consequences of drift. Because the strain of neighbor relationships was identified as a major consequence of pesticide drift, this kind of conversation facilitation was seen a great need. Objective 4:A framework for a full research project was developed with objectives and research questions largely defined.A logic model was partially developed.The central objective of the proposed project is to evaluate the direct and indirect costs of inadvertent pesticide contamination on organic growers, and determine how these costs impact the production decisions of these producers and the communities in which they live and work. Potential research questions include: 1.To what extent do organic growers lose revenue due to inadvertent contamination? 2.To what extent and in what ways do organic growers suffer indirect declines to revenue as a sector? 3.To what extent and in what ways do organic growers suffer non-tangible harms to their emotional and mental health? 4.To what extent and in what ways are agricultural communities harmed by inadvertent contamination? 5.What are the potential policy, advocacy, research, or other interventions that might mitigate the direct and/or indirect costs of inadvertent pesticide contamination for organic growers? 6.Are the threats to a farm's organic certification and crop marketability different depending on the cropping system and marketing strategy? 7.To what degree does the risk of contamination differ for large and small farms? 8.How are processors impacted? How is the impact spread across the supply chain? 9.What mechanisms are there to share risk between growers and processors? Overall, our events, activities and products largely contributed to a change in knowledge and somewhat of a change in action. Specifically, those who were involved in the survey development, implementation, results analysis and reporting learned from each other's experiences and perspectives and learned about the experience of organic farmers and food handlers from across the US. That knowledge was turned into action by developing a framework for a research project that would comprehensively assess the monetary and non-monetary costs of contamination for organic farmers. **Publications** - Type: Websites Status: Published Year Published: 2020 Citation: https://www.organic-center.org/site/protecting-organic-farmers-pesticides **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience:The target audience for our project includes organic farmers; organic certifiers; food handlers, processors, manufacturers, and distributors; general public (consumers), academic researchers, and policy makers. However, our education and outreach efforts during the reporting period were hampered by the COVID-19 pandemic. Changes/Problems:The COVID-19 pandemic prevented us from organizing an in-person, multi-day planning meeting during the reporting period. Instead, the project team and advisors met via videoconference several times during 2020-2021. We moved

forward with our survey (to fulfill Objectives 1-3), but had to postpone our Planning Summit until early 2022. We plan to submit a full OREI project proposal in 2022 or 2023, depending on submission deadlines. The COVID-19 pandemic also prevented us from hosting in-person meetings (listening sessions, workshops, etc.) with organic producers, processors, and handlers. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest?Survey results were reported (via videoconference)to the project team, advisors, and invited guests in November 2021. A comprehensive survey summary report and white paper are in progress. We also plan to share our results via social media and newsletter networks of The Organic Center. What do you plan to do during the next reporting period to accomplish the goals? Having received a no-cost extension for the project, we plan to hold a Planning Summit (via videoconference) in January 2022 to begin discussing and preparing a full OREI proposal. The proposed project will be guided, in part, by our survey results. The Planning Summit, as well as follow-up team meetings, will result in submission of a full OREI project proposal (Objective 4). During the next reporting period, we also plan to share our survey results using multiple dissemination strategies (e.g., white paper, social media, newsletters, etc.). **Impacts** What was accomplished under these goals? Our activities during the reporting period contributed significantly to objectives 1-3. We held a kick-off meeting (7/28/20) and survey development meeting (9/16/20)via videoconferencefor the project team. We then developed a survey instrument (\"Inadvertent Pesticide Contamination Survey: A Survey of Certified Organic Producers, Processors, and Handlers\") in September-October 2020. The survey included questions about the extent of inadvertent pesticide contamination, mitigation strategies (and their effectiveness), research/outreach needs, and opinions about testing, impacts, consumer behavior, and other topics.A survey draft was shared with your project advisors for feedback in November 2020. The survey instrument and list of email addresses from the USDA Organic Integrity Database were provided to Washington State University's Social and Economic Sciences Research Center (SESRC) in December 2020. SESRC programmed a web version of the survey (January 2021), received IRB exemption for the study (February 2021),and sent multiple emails to 3,020 organic producers, handlers, and processors (February-April 2021). The survey then shifted to an open-access link until June 2021. The survey response rate was approximately 5% (160 respondents). Data cleaning, coding, and preliminary analyses took place in August-September 2021. **Publications**

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Collaborative Plant Breeding Network Development for Organic Systems in the Upper Midwest

Accession No.	1023494
Project No.	WIS03090
Agency	NIFA WIS\
Project Type	OTHER GRANTS
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Proposal No.	2020-02247
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Investigator(s)	Dawson, J. C.; Colley, MI, .; Formiga, AL, K.; Enjalbert, NI, .
Performing Institution	UNIV OF WISCONSIN, 21 N PARK ST STE 6401, MADISON, WISCONSIN 53715-1218

NON-TECHNICAL SUMMARY

There is a critical need in organic agriculture to breed crop varieties adapted to organic production systems. Equally critical is the need to adapt to changing climatic conditions, through more decentralized testing and regional selection of varieties. We will build capacity among farmers, plant breeders and seed companies, to ensure that farmers\' evolving needs and unique body of knowledge drive the development of the crop varieties made available to them. Advancements in real-time information sharing, decentralized participatory methodology, analysis tools for large datasets from heterogeneous environments, and techniques for facilitating multi-stakeholder collaboration are necessary to equip organic plant breeders to succeed in serving organic farmers. In pursuit of these goals, the research and outreach objectives of this project are to: 1) Build collaborative plant breeding and trialing capacity among Midwest organic farmers, independent plant-breeders, organic seed companies, and organic inspectors via advanced training and an integrated community of practice; 2) Release a suite of plant breeding tools in the new online platform SeedLinked that facilitate collaboration among farmers, independent plant-breeders, organic seed companies, and organic inspectors; 3) Develop and release varieties of sweet peppers and tomatoes exhibiting priority traits for Upper Midwest organic production using participatory methods and SeedLinked to engage organic fresh-market vegetable farmers in the breeding process; 4) Train a graduate student in participatory methods and breeding for organic systems; 5) Promote regional breeding network development, and improved organic seed use across the country via online training opportunities and tools. The long-term success of organic farms in a changing climate and unpredictable agricultural market depends on a resilient seed system. Dynamic participation and frequent feedback should drive evolution and adaptation. In a robust seed system, short term goals (e.g. specific breeding objectives) are pursued in tandem with the long-term work of strengthening the relationships that nurture and enable collaboration. Effective decentralization requires capacity building for farmers and other actors who have not traditionally done variety trialing, plant breeding or seed saving. This project facilitates the development of improved plant breeding methods for organic agriculture. The project will strengthen relationships between farmers, public and private sector breeders, non-profit seed organizations, regional seed companies and organic certification agencies, to facilitate future collaborative breeding projects for organic agriculture.

OBJECTIVES

Varieties bred for organic systems work better for organic farmers. However, there are a shortage of plant breeders in either the public or private sector working on organic systems, and many organic farmers still rely on varieties bred for conventional systems. There is a critical need to build capacity for farmers, plant breeders and organic seed companies to work together to ensure that farmers\' evolving needs and unique knowledge drive the development of the crop varieties available to them. Advancements in real-time information sharing, decentralized participatory methodology, data analysis tools for large datasets from heterogeneous environments, and techniques for facilitating multi-stakeholder collaboration are necessary to equip organic plant breeders to succeed in serving organic farmers. The long term goals of this project are to:1) Increase the number and availability of fresh market vegetable crop varieties well-suited to organic production in the Upper Midwest. This region is currently underserved by vegetable seed companies but is predicted to be of growing importance with changes in climate.2) Build and sustain a robust regional network of organic farmers, plant breeders, seed companies and organic certifiers working together to improve crop varieties for organic production and increase the use of organic seed on organic farms.3) Build the pipeline of professional plant breeders, including independent entrepreneurs, breeders at regional seed companies, and public sector programs dedicated to breeding for organic systems and using participatory methods.4) Encourage collaborative organic variety improvement networks in other regions to meet farmers\' emerging needs in a regional context. In pursuit of these goals, the research and outreach objectives of this project are to:1) Build collaborative plant breeding and trialing capacity among Upper Midwest farmers, independent plant-breeders, regional organic seed companies, and organic certifiers through an integrated community of practice, advanced training opportunities, and a nationally available online toolkit.2) Test and improve Seed Linked functionality for farmers, breeders, and organic certifiers to effectively collect, share, and analyze data to support decentralized collaborative breeding and variety trialing.3) Develop models for cross-sector collaboration between independent breeders, public sector programs and organic seed companies. Enhance graduate student education by providing experience across these sectors to develop advanced breeding lines and commercialize varieties exhibiting priority traits for Upper Midwest organic production, employing collaborative breeding methods.

APPROACH

Objective 1.The combination of online, in-person, classroom style and peer-to-peer learning opportunities proposed above will simultaneously enhance individual skills and create space for people to share skills, ideas and lessons learned from experience with others who can test and deepen their thinking. The combination of an active, moderated listserv for those interested in collaborative plant breeding and in-person networking opportunities will ensure that community members can form strong personal relationships to support their individual work. Similar models for building a community of practice have been successful in this field. Live webinars are an appropriate format for offering education on advanced topics. The target audience for these presentations is geographically dispersed and familiar with online educational opportunities. The content and primary outreach for the webinars will be focused on the Upper Midwest, but webinar registration will be open nationally. This serves the purpose of bringing people with diverse experiences, questions and contexts into the virtual \"room\" to enhance each other\'s learning. The online Toolkit will be the primary method for supporting community of practice members\' individual learning and for extending the results of this project to other regions. The video format for conveying important techniques for beginning farmer-breeders will help the audience visualize the information being conveyed, and will add a personal connection and sense of story to the technical aspects of breeding work. The methods for the Climatic considerations for seed crops in the Upper Midwest publication will include a review of existing literature, targeted interviews with at least ten Midwest seed producers and plant breeders, and consultation with experts in seed pathology and other seed quality issues. Objective 2.SeedLinked founder Enjalbert and staff developers Kastman and Thandaserry will make improvements to the platform from feedback obtained through the 2019 beta test. A second phase of improvements will target plant breeders, farmers engaged in breeding projects, and organic certifiers. UW-Madison and OSA will support SeedLinked staff by engaging farmers from their Upper Midwest Networks and facilitating feedback-sharing between farmers, breeders, and SeedLinked. Our workflow follows lean methods, generally proceeding in two-week sprints, with a target deliverable at the end of each sprint. During each successive sprint, we will fix bugs found in previous sprints and respond to user feedback, in addition to working on the tasks assigned to that sprint. Development feedback loop: The SeedLinked team will engage the SKC trialing network, Seed Savers Exchange, the Experimental Farm Network, Nature and Nurture Seeds and KC Tomatoes in designing, testing and improving Seedlinked functionalities for decentralized breeding. Following an iterative process engaging the direct platform users, we will constantly improve platform functionalities via this feedback loop. The SeedLinked development team will also do multiple site visits during growing season to validate and refine user experience. For breeding trials, a survey will be sent to trial managers and participants at the end of each season to solicit

particular feedback on platform functionality. SeedLinked will engage Midwest organic certification agencies in improving Seedlinked\'s functionality for helping certifiers learn about new organic varieties and supporting farmers in improving organic seed usage. Objective 3.Tomato Breeding: We will follow a two-pronged approach to A) select and commercialize existing breeding lines and B) create populations with better resistance to foliar diseases and cracking seen in the Upper Midwest. Year 1-A) The performance of the best existing lines within the 45L23 and SGLL breeding pools will be tested in Kansas City, MO, Madison in Southern WI, and Spooner in Northern Wisconsin on certified organic land. 3-5 lines will be selected for on-farm trials in the region and potential commercialization. B) The best existing lines will be crossed to parents identified in SKC trials or from other breeding programs as more resistant to foliar diseases and cracking in the more humid Upper Midwest. Crosses will be made to generate a diverse population that can be used for on-farm trials and selection. The crossing will be done in the organic greenhouse facilities at UW Madison. Year 2-A) The lines selected for on-farm trials will be sent to 10 farms each, and farmers will use the SeedLinked application to provide feedback on each line to the breeding team. The graduate student and Enjalbert will help farmers with the application and will evaluate the new tools so that continued improvements can be made. Data will be sent to interested organic seed companies. The Dawson lab will recruit farmer collaborators and manage seed distribution. B) The segregating populations will be advanced in the field in Kansas City, MO, Madison and Spooner and sent to 5 farmers interested in conducting on-farm selection. Farmers will use the new breeding functionalities of SeedLinked, and with the assistance of the graduate student will select plants and send seed to UW Madison. Selected seed will be increased over the winter in the organic greenhouse at UW Madison. Year 3- A) The best 1-2 lines identified in multi locational trials will be used for seed stock production in Kansas City to be trialed by organic seed companies, and will be trialed in SKC research station trials as well as in the larger SKC on-farm trialing network. B) The advanced selected individuals will be evaluated in the field in Kansas City, Madison and Spooner and sent to the same 5 farmers. Farmers will again use the SeedLinked application to share feedback with the breeding team and select individual plants for advancement. Selections will be advanced in the greenhouse over the winter 2022, and sent out to a larger network of on-farm trials in the year following the project (essentially entering the \"A\" strategy for release if they are deemed promising enough).Pepper Breeding (Nature and Nurture Seeds) Year 1-Conduct screening trials for germplasm accessions and varieties that may be good sources of early yield and stronger disease resistance in Ann Arbor, MI, Madison, WI and Spooner, WI under certified organic conditions. The graduate student will help conduct a search of germplasm sources and in accessing varieties from other breeding programs. Select parents and cross with existing high performing open pollinated varieties in the winter in a certified organic greenhouse at UW Madison. Year 2-Grow out F1 individuals in Ann Arbor and eliminate any families that do not combine early yield and disease resistance. Harvest F2 seed and advance to F3 in an organic greenhouse at UW Madison. Year 3-Plant F3 families in Ann Arbor, Madison and Spooner under certified organic conditions. Send F3 seed to 10 collaborating farms. Select among families and within families for flavor, early yield, and disease resistance. Farmers will use the new breeding functionalities of SeedLinked, and with the assistance of the graduate student will select plants and send seed back to the project partners, with the help of the graduate student if desired. Selected F4 seed will be increased over the winter in the organic greenhouse at UW Madison. F5 seed of the most promising families will be put into stock seed production for a new OP to be sent out to on-farm trials with the SKC and evaluated for potential commercialization through Nature and Nurture Seeds. Progress 09/01/20 to 08/31/24 Outputs Target Audience: Our target audience is primarily farmers, independent seed breeders, seed companies interested in organic seed and organic certifiers. We reached all these audiences with information about the project through the on-farm trials conducted, our webinar series, field days, online platforms and newsletters. Changes/Problems:The first two years of this project were significantly impacted by the COVID pandemic. In year 1, we had almost complete restrictions on field work and travel, making it difficult to carry out the research and outreach components of the project. A key staff person left to take care of family responsibilities, and we struggled to rehire during the pandemic. In addition, we had a field crew labor shortage during the field seasons in 2021 and 2022. This meant that scientific and professional staff were involved in keeping fieldwork going, which reduced the time spent on other project activities. We were able to successfully staff the project for the remainder of the grant term, but the early restrictions on research, travel and hiring resulted in substantive delays in parts of the project that required this expertise, such as data analysis and publication. We stayed on-schedule for the on-farm trials and seed multiplication so that we did not lose years of breeding work, but publications are still being wrapped up. There were also lingering effects of COVID and inflation on farmer participation in trials and in-person events as many farmers are short-staffed and have less time available for research and networking. What opportunities for training and professional development has the project provided?We have had the opportunity to engage many students and other professionals in this project. In this section we are only listing training for students and staff that was not included in the professional development described in the accomplishments from Objective 1, which focused on developing a community of practice with training opportunities for professionals. A graduate student in the Dawson lab has contributed to this project, in particular on-farm selection and evaluation of breeding strategies. She is supported on a fellowship that covers her stipend and tuition but no research funding. She will defend her

PhD thesis in March, 2025, with peer-reviewedpublications to follow. A masters student from Uruguay completed her 6-month masters research internship with our program working on this project as well as other OREI funded trials in our lab. We have had several undergraduate students and recent graduates who have participated in the trials to learn more about organic field research and breeding. Four academic staff members have gained professional development experience managing on-station field trials, on-farm trial logistics, greenhouse seed multiplication, and crossing blocks and data collection from field trials. Research station field days and conference workshops/roundtables provided professional development opportunities for students, research and extension staff and educators, interested in developing or being involved with participatory breeding projects, (in addition to providing training to farmer and professional participants in the field days). How have the results been disseminated to communities of interest?Results have been distributed through several mechanisms. Participants receive information through community of practice, which we reach through the email listserv, the Organic Seed Commons Midwest Network and the SeedLinked trial feeds, as well as direct email updates. The broader organic seed community gets updates through newsletters of the Organic Seed Alliance, SeedLinked and eOrganic. We have also shared updates on the Organic Seed Alliance blog throughout the project. The OSA email newsletter has over 11,750 contacts (at least 1,300 of which known to be Midwest based, and more than 4,750 self-identified as farmers or seed practitioners). The SeedLinked newsletter has about 2200 reads/issue. Trial results are shared within and outside the SeedLinked platform, using its sharing capacity. On average, 1.1K unique users and 250 authenticated growers visit the platform per month. The broader organic farming and research communities have gotten information on project results through conference presentations and workshops as well as eOrganic webinars. Summer field days and public events presented results of the on-farm trials and selections to attendees and conducted flavor evaluations of the breeding lines most likely to be released from the project. In addition, the resources developed through the project, including webinars, tutorials and written guides, are freely available from eOrganic, the Organic Seed Alliance, SeedLinked and UW Madison. 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: We developed a community of practice through online and in-person opportunities for organic seed professionals to interact, learn from each other, and build connections. Specific outreach activities and educational products are listed in the other product section of this report and summarized below. The community of practice includes about 100 seed producers, small seed companies, independent plant breeders and non-profit staff in the Upper Midwest working on organic variety development and seed production. In addition we have a large network of several hundred growers who participate in trials, either for variety testing or collaborative plant breeding. We continued to strengthen our network of farmers participating in on-farm trials for collaborative plant breeding, with 73 trial participants in year one and 120 participants in our collaborative breeding trials in the final year. We also have many growers who participated in our community of practice events who are involved in on-farm variety trials funded through different sources. These growers may not wish to be seed producers or interested in on-farm breeding, but are eager to learn and contribute to improved varieties for organic systems in our region. Our in-person events included field days in Minnesota (2021), Wisconsin (2022), and Michigan (2023, 2024), a public-facing event in Wisconsin (2023), and winter conference roundtables each year at the Organic Vegetable Production Conference and the Marbleseed Conference, both in Wisconsin. Virtual Midwest Seed Meetups and the Organic Seed Commons space and a listserve are hosted by the Organic Seed Alliance (OSA), as well as an online platform hosted by SeedLinked where participants can ask questions, post photos and share information. We conducted a training course for on-farm and collaborative plant breeding, which is available through eOrganic. We also produced a series of training webinars for SeedLinked specifically for farmers, plant breeders, trial managers and organic certifiers, available through SeedLinked. We developed a guide on Climate Considerations and Risks for Seed Production in the Upper Midwest, available from OSA. All resources are freely available to the public. Objective 2: We added significant functionality to the SeedLinked platform to enhance the ability of farmers, breeders and researchers to collect and analyze data, and to aid organic farmers and certifiers in meeting organic certification standards for sourcing organic seed. Major additional functions include: Triadic experimental design: Each grower receives a set of three varieties as an incomplete block design with analysis using non-parametric (rank-based) statistics. This allows more varieties to be included in a trial and expands the number of participants. Tasting trials: any participant or manager can set up a taste test with varieties or breeding lines. The public can participate at an event such as a field day through scanning a QR code. The tasting trial also displays real-time results with variety names, while samples remain coded. Single-trial rating: this allows users to set up a QR code for a single trial site, so that multiple people can rate the same trial (for example, field day participants can rate a trial they are visiting). This also allows multiple farm staff members to participate in rating the trial if they are all managing the same plots. Survey trial: Users can create a survey trial if they are testing out new varieties on their farm and want to add minimal data to keep track of performance in advance of a potentially larger trial. This is useful for early stages of breeding projects as well as for farmers trying to replace a conventional variety with an organic variety. Check varieties: farmers can now add their own check variety to a trial, if they want to plant their standard variety in the trial to create their own farm standard, particularly across different trials of the same crop type. Quantitative data: Trial managers can collect

quantitative data on certain traits in addition to the 1-5 scale used by most trial participants. Organic Seed Search: this allows farmers and certifiers to see whether a variety is available as certified organic seed across more than 20 seed companies and also allows them to look at other varieties recommended by growers as being similar to varieties they are looking for. They can also search by desired characteristics to find varieties that can potentially fit their market and climate needs based on aggregated data. Trial feed: this allows participants to communicate with each other and trial managers, share photos and ask questions. Trial-specific feeds allow for more focused discussion of trial varieties and results. In addition to major features, the behind-the-scenes architecture has been improved to ensure a better user experience and more intuitive interface. This includes tutorials and a better onboarding process for trial managers and participants as well as a focus on direct contact with users to ensure that they feel engaged in the community of practice. In addition, specific capabilities were added to help trial managers set up and manage trials easily: 1. organization profiles with multiple users for one organization, 2. expanded variety database management, 3. full BRAPI compliance for cross-compatibility across databases, 4. picture tagging with traits, 5. improved displays of trial results so that trial managers can use graphical output more directly, 6. improved filtering options including climate, soil and management practices, and 7. improved privacy features and sharing settings for participants and managers. These improvements have resulted in a steady yearly increase in the number of trials conducted by trial managers, an increase in the number of overall participants in both breeding and variety trialing, an increase in the trial completion rate and an increase in trial engagement by growers. We have established a user group who are running trials each year and directly interfacing with farmers and growers to continually improve the software platform and work on new features in response to organic farmer requests. Objective 3: We have successfully developed a model for collaborative plant breeding which helps independent plant breeders access more extensive data across their region, giving them better information on regional adaptation and grower preferences. The collaborative trial network allowed independent plant breeders Erica Kempter and Keith Mueller to send out seed of third-generation (F3) lines to participating farmers, expanding their population sizes and range of testing conditions considerably. In the first year of the project, about 20 growers participated in each trial, increasing to about 40 growers each in the last year. These growers helped select successful lines, and seed was shared back with the independent breeder as well as being continued on their farm and other participating farms. At the end of the project, there are three varieties being released through the independent breeders which will also be part of the Open Source Seed Initiative (OSSI) so that participating growers can continue to save seed and conduct selection, or they can purchase organic seed through Nature and Nurture Seeds and potentially other organic regional seed companies. In addition there are a number of promising breeding lines of tomato and pepper that will continue to be evaluated in the trialing network either for release or to use as parents to develop new organically-adapted varieties. Publications Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Dawson, J.C. 2024. Scaling up participatory research to develop varieties for diversified regional farming systems. Invited Seminar, Ohio State University. February 14, 2024. Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Dawson, J.C. 2024. Participatory Research for Resilient Regional Seed Systems. Invited Seminar, University of Illinois at Urbana-Champaign. October 23, 2024. Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Dawson, J.C., 2023. Connecting local food systems to regional plant breeding through flavor. Invited keynote to the National Association of Plant Breeders Annual Meeting. July 17th, Greenville, SC Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Dawson, J.C., 2023. Participatory research for resilient regional seed systems. Weston Roundtable, University of Wisconsin-Madison. Feb 16. Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: Dawson, J.C. 2022. Strategies for developing varieties for diversified farming systems. Invited talk at the Danforth Center Plant Breeding Symposium. Danforth Plant Sciences Center, March 9 Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: Dawson, J.C. 2022. Plant breeding strategies for increasing regional crop diversity. Invited talk at the Plant Breeding Seminar Series. Iowa State University, February 23 Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: Dawson, J.C. 2022. Variety selection for regional food systems. Invited talk at the Plant Sciences Symposium on Specialty Crop Breeding. North Carolina State University, February 10 Type: Conference Papers and Presentations Status: Other Year Published: 2021 Citation: Dawson, J.C. 2021. Plant Breeding for Organic Systems. Invited talk in the Symposium on Breeding for Systems: Resilient Crops and Ecosystem Services. Crop Science Society of America Annual Meeting, November 8 Type: Conference Papers and Presentations Status: Other Year Published: 2020 Citation: Dawson, J.C., Enjalbert, N. 2020. Seed to Kitchen: Participatory Variety Trialing to Improve Selection Methods for Vegetable Flavor and Local Adaptation. Invited speaker, Crop Science Society of America Annual Meeting. ASA-CSSA-SSSA. Online, November 11. Type: Conference Papers and Presentations Status: Other Year Published: 2021 Citation: Dawson, J.C. and Enjalbert, N. 2021. Can crowdsourcing technology revolutionize collaborative breeding and testing? Organic World Congress, Rennes, France. September 9. Joint presentation. Progress 09/01/22 to 08/31/23 Outputs Target Audience:Our target audience is primarily farmers, independent seed breeders, seed companies interested in organic seed and organic certifiers. We reached all these audiences with

information about the project through the on-farm trials conducted, our webinar series, field days, online platforms and newsletters. Changes/Problems:Some participants and target audience members have expressed difficulty understanding and using the Organic Seed Commons network. Support from OSA staff has been provided to help users understand functionality, but overall engagement on the platform has been less than desired. Further effort will be made to understand obstacles and facilitate more activity and communication within the network. Ongoing labor shortages unrelated to the project continue to challenge the ability of farmers to fully participate. What opportunities for training and professional development has the project provided?The summer field days provided professional development opportunities for students, educators, and growers interested in developing or being involved with participatory breeding projects. Online community events and Organic Seed Commons network allowed for peer-to-peer learning opportunities and information exchange. The webinar series provided professional development for a wide range of farmers and educators interested in seed production and breeding. The on-station trials provided professional development for 2 staff members and several undergraduate students. On-farm trials provided professional development for over 50 participants and their staff. How have the results been disseminated to communities of interest?Information about the webinar series and highlights from the field day were posted and shared through blog posts on the Organic Seed Alliance website and sent through email newsletter to over 11,750 contacts (at least 1,300 of which known to be Midwest based, and more than 4,750 self-identified as farmers or seed practitioners). Information was also distributed through the SeedLinked newsletter, with about 2200 reads. Trial results are shared within and outside the SeedLinked platform, using its sharing capacity. On average, 1.1K unique users and 250 authenticated growers visit the platform per month. Summer field days presented results of the on-farm trials and selections to attendees and conducted flavor evaluations of the lines most likely to be released from the project. What do you plan to do during the next reporting period to accomplish the goals? Objective 1 - we will complete the collaborative plant breeding toolkit, assembling educational products and publications from this project into a single online repository which will continue to be available after the project ends. We will complete publication of a guide on climate considerations for vegetable breeding and seed production in the Upper Midwest. We will continue community of practice activities including winter meetings and discussions on the organic seed commons platform. Objective 2 - we have completed the deliverables for this objective and will focus on receiving user feedback on breeder tools in SeedLinked developed through this project. Objective 3 - we will conduct an additional season of on-farm trials for the most advanced lines which have been selected for release, as well as returning selected lines to farmers which we have advanced one generation in our greenhouse. A publication will be submitted with the results of the collaborative selection experiment, and each case study will be summarized on eOrganic. Varieties developed through this project will be released through the open-source seed initiative. Impacts What was accomplished under these goals? Objective 1: Build collaborative plant breeding and trialing capacity Deliverables- COP, advanced training, online toolkit We organized and hosted an online series of six webinars titled \"Practical Training for On-Farm and Collaborative Plant Breeding\" in January and February 2023. These interactive webinars included presentations from project team members as well as external content experts from universities, privately owned seed companies, and non-profit organizations. There was time dedicated to questions and answers at the end of each webinar. These are available through the project website at eOrganic and the eOrganic YouTube channel. We also developed several tutorial videos on using SeedLinked which are available through the SeedLinked YouTube channel. We hosted an on-farm field day at Nature & Nurture Seeds Farm in Ann Arbor, Michigan featuring the breeding lines from this project. In addition to demonstrations of seed cleaning methods and discussion of best practices for organic seed production in the Midwest, participants were able to sample and evaluate this project\'s tomato breeding lines in comparison to commercially available varieties. A blogpost highlighting the field day was posted by Organic Seed Alliance and sent out through digital newsletters. Within the online Midwest Regional Seed Network on the Organic Seed Commons platform, we hosted a virtual meet-up in December 2022 to discuss breeding projects and seed production methods. The network has grown to 91 members. In addition, the Upper Midwest Seed Growers email list-serv has grown to 86 members. Objective 2: Test and rapidly improve SeedLinked functionality Deliverables - VDP Architecture, Data Sharing, Ontology, Trial Design, Data Analysis, Certifier and grower decision-making tools In 2023, our efforts were concentrated on enhancing user onboarding and engagement, implementing extensive UX/UI improvements, optimizing data and trial visibility, and refining sharing and privacy features. The following summarizes the accomplished deliverables: Full Social Feed Deployment: Introduced \@mentions, #hashtags, and Follow features to enrich the user experience within the social feed. Trial Results Page Enhancement: Improved the trial results page with the inclusion of error bars and trial condition filters Enhanced sharing capabilities and privacy features, contributing to an improved UX/UI. Picture Tagging and Visibility: Implemented picture trait tagging and enhanced visibility in all platforms. Mobile and Web Embedded Walkthrough: Developed a full mobile and web embedded walkthrough Developed video tutorials and First-Time User Experience (FTUE) prompts, providing guidance to all users. Notably, this initiative resulted in a 10% increase in participation for the main national trials compared to 2022. Trial option Improvements: Enhanced the tasting trial with improved UX and code options. Introduced a subset trial (Triadic) with increased combination flexibility. Launching 2 new trials

type this fall: Survey and flex trial Organizational Architecture: Designed and implemented an organizational architecture which allows multiple users per organization This was requested by organizations with multiple breeders and trial managers. Each organization now has a dedicated page within SeedLinked Social, enhancing overall visibility Interoperable Data Model: Developed a comprehensive data model designed to be fully BRAPI-compliant Now fully interoperable for future implementations in subsequent projects Variety Management Added a complete variety management space accessible to trial managers Trial managers can now add and edit varieties efficiently, streamlining the process Objective 3: Develop models for collaboration between independent breeders, public sector programs, and organic seed companies Deliverables - Tomato Breeding Case Study, Pepper Breeding Case Study We worked with breeders Keith Mueller and Erica Kempter to distribute mid generation breeding lines to participating farmers and gardeners. These lines were the result of on-farm and independent breeder selection, and were advanced a generation in the West Madison greenhouse over the winter of 2022-2023. We had three trials; two mid-generation tomato trials and one mid-generation pepper trial. The tomato trials included lines from Keith Muller with 31 participants, of which 12 have completely submitted data and the rest are in progress, and lines from Erica Kempter with 45 participants, of which 19 have completely submitted data and the rest are in progress. The pepper trial had 43 participants, of which 21 have fully completed the trial and the rest are in progress. Several growers returned seed of selections. We also grew out all these selections at the West Madison Agricultural Research Station to evaluate uniformity and compare selections. We are growing out both on station and on farm selections in the greenhouse over the winter to advance a generation and will send seed back to participants in the spring for a final year of on-farm evaluation of advanced lines. We are nearing release of two tomato varieties in addition to the creation of several very promising breeding lines that will continue to be evaluated in on-farm trials. Publications Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Dawson, J.C., 2023. Connecting local food systems to regional plant breeding through flavor. Invited keynote to the National Association of Plant Breeders Annual Meeting. July 17th, Greenville, SC Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Dawson, J.C., 2023. Participatory research for resilient regional seed systems. Weston Roundtable, University of Wisconsin-Madison. Feb 16. Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: Dawson, J.C. 2022. Strategies for developing varieties for diversified farming systems. Invited talk at the Danforth Center Plant Breeding Symposium. 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Seed to Kitchen: Participatory Variety Trialing to Improve Selection Methods for Vegetable Flavor and Local Adaptation. Invited speaker, Crop Science Society of America Annual Meeting. ASA-CSSA-SSSA. Online, November 11. Type: Conference Papers and Presentations Status: Other Year Published: 2021 Citation: Dawson, J.C. and Enjalbert, N. 2021. Can crowdsourcing technology revolutionize collaborative breeding and testing? Organic World Congress, Rennes, France. September 9. Joint presentation. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: We reached our target audience with information about the project starting at the 2022 Organic Seed Growers Conference (OSGC), then at Organic Vegetable Production Conference, MOSES Conference, and virtual community meeting held through Organic Seed Commons. We also reached our audience through the summer field day, Farm to Flavor Showcase, and on-farm trials. Changes/Problems: Some participants and target audience members have expressed difficulty understanding and using the Organic Seed Commons network. Support from OSA staff has been provided to help users understand functionality, but overall engagement on platform has been less than desired. Further effort will be made to understand obstacles and facilitate more activity and communication within network. Some farmers expressed difficulty being able to make time in schedule to attend in-person field day, but videos were taken and are currently being edited to share presentations with those unable to attend. There were also lingering effects of COVID on participation of in-person events and on labor; many farmers are short-staffed and have less time available for research and networking. What opportunities for training and professional development has the project provided?The West Madison field day provided professional development opportunities for students, educators, and growers interested in developing or being involved with participatory breeding projects. Online community events and Organic Seed Commons network allowed for peer-to-peer learning opportunities and information exchange (see other products). The on station trials provided training for 2 staff members and 4 undergraduate students. How have the results been disseminated to communities of interest? Trial results are shared within and outside the SeedLinked platform. On average, 1.1K unique users and 250 authenticated

growers visit the platform per month. A number of outreach events were held (see other products) which distributed results and built the collaborative plant breeding network. Highlights from the field day were posted and shared through a blogpost on Organic Seed Alliance website and sent through email newsletter to over 9,000 contacts (at least 875 of which known to be Midwest based, and almost 3,300 more self-identified as farmers or seed practitioners). A blogpost on eOrganic about the Farm to Flavor outreach event included information on the project. The project website includes videos for trial participants, links to trial results and links to the blogposts: <https://eorganic.info/collaborativebreeding>. What do you plan to do during the next reporting period to accomplish the goals? We will continue with the development of the community of practice and outreach activities described in the grant narrative including webinars, videos, workshops and field days. Plans for this coming winter include conducting six webinars this coming winter in collaboration with Michael Lordon and other project members. We will continue the development of SeedLinked functionality as described in the grant narrative, including the variety development process architecture, improvements to data analysis capabilities, and trial design for breeding programs. The tomato and pepper case studies will also continue, and a publication on their methodology will be submitted. **Impacts** What was accomplished under these goals? Objective 1: Build collaborative plant breeding and trialing capacity Deliverables- COP, advanced training, online toolkit Within the Midwest Regional Seed Network hosted on Organic Seed Commons, a synergy space meeting was held during the February 2022 Organic Seed Grower's Conference. The online regional network has grown to 76 members. Other activity in the network includes a virtual community meeting held in April, plus 17 different postings with an additional 16 comments. We hosted an on-farm field day at the University of Wisconsin West Madison Agricultural Research Station featuring the breeding lines from this project along with other participatory breeding opportunities working with sweet corn and carrots. A blogpost highlighting the field day was posted by Organic Seed Alliance and sent out through digital newsletters. Our team also co-led a roundtable discussion at the 2022 MOSES conference, with discussion of the regional seed system. This project also had a booth with information to recruit trial participants. We shared about the project to more than 200 people and provided samples of the breeding line tomatoes at the Farm to Flavor Showcase in Madison, WI, co-hosted by Culinary Breeding Network, Seed to Kitchen Collaborative, and Artisan Grain Collaborative. A blogpost highlighting the showcase was posted by eOrganic (<https://eorganic.info/collaborativebreeding>) and sent out through newsletters. eOrganic also sent out newsletters for other public events and to recruit trial participants, and performs Ongoing maintenance of project website including videos for trial participants, links to trial results and links to the above report and the highlights of the Midwest collaborative field day (<https://eorganic.info/collaborativebreeding>). Objective 2: Test and rapidly improve SeedLinked functionality Deliverables - VDP Architecture, Data Sharing, Ontology, Trial Design, Data Analysis, Certifier and grower decision-making tools During this last year, two major areas of focus were to improve user engagement and Organic Search 2.0. Following a living labs framework, most partners' feedback evolved around increasing engagement of growers. So, the SeedLinked team has been focusing on improving UX of all 3 apps, adding functionality such as better rating system, more guidance for growers use, and a better onboarding process. To date in the 2022 trial season, we had an average of 49% review rate out of 521 growers who planted a trial, a significant increase from the past year. We also added a full social feed on to increase engagement and communication. The prototype version showed that 30% of active growers engage in the Feed. As we just launched the full Feed, we will report usage next year. From the trial manager side, SeedLinked platform now includes full Checks capacity within all trial types, QR code rating for single location trial, and entry list ordering. We started to integrate breeding pipeline architecture in the backend, including things such as generational stage and variety naming. We also are working on allowing users to self-upload varieties and a new trial results display. The largest project of the past year was the development of the marketplace/Organic Seed Finder with integration of 13 seed companies. Objective 3: Develop models for collaboration between independent breeders, public sector programs, and organic seed companies Deliverables - Tomato Breeding Case Study, Pepper Breeding Case Study We worked with breeders Keith Mueller and Erica Kempter to distribute early and mid-generation breeding lines to participating farmers and gardeners. We had four total trials, including two early generation tomato trials (44 and 24 participants), one advanced generation tomato trial (26 participants), and one early generation pepper trial (44 participants). Eighteen participants returned seeds selected for continued use in the breeding program. We also grew out all the selections from the previous year at the West Madison Agricultural Research Center and made additional selections. We are growing out both on station and on farm selections in the greenhouse over the winter to advance a generation and will send seed back to participants in the spring. **Publications** **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience:Our target audience is primarily farmers, independent seed breeders, seed companies interested in organic seed and organic certifiers. We reached all these audiences with information about the project starting at the Growing Stronger conference roundtable, the field day in Minnesota and the webinar for certifiers. We also reached growers through on-farm trials. We will do much more outreach during the next few years of the project as activities were constrained due to COVID restricting in person gatherings and general fatigue of online platforms. Changes/Problems:Our outreach in person was significantly hampered by COVID related restrictions. In addition, we had a field crew labor shortage during the field season which meant that

project staff was involved in keeping fieldwork going, which reduced the time spent on other project activities. Due to staffing changes in both the subawardees and UW Madison programs, we would also like to hire a program manager rather than a graduate student for this project. The graduate student working on the project is funded through other sources for the duration of the project but has other responsibilities related to that funding. To accomplish the project goals, we would like to hire a knowledgeable person to oversee outreach and communication. OSA had staffing challenges in 2020 and 2021 due to COVID-19. Beginning in 2022, we will be bringing on Michael Lordon at 50% FTE (replacing Healy) to manage our scope of this project. What opportunities for training and professional development has the project provided?A graduate student in the Dawson lab is working on the collaborative breeding project, funded by an internal grant that covers tuition and a stipend but not research expenses. In addition, a masters student from Uruguay completed her masters research internship with our program working on this project as well as other OREI funded trials in our lab. We have had several undergraduate students and recent graduates who have participated in the trials to learn more about organic field research and breeding. Many (>15) one on one training were done by the SeedLinked team for independent breeders and trial managers. How have the results been disseminated to communities of interest?We have only been through one field season and so do not yet have results to disseminate through formal extension or publication channels. For preliminary (one-year) results, SeedLinked platform built-in results sharing and Explore functionalities allow to connect all results with proper experimental design and analysis for any growers to see, interact with, and use. More than 850 monthly unique users go on SeedLinked. We also held several virtual webinars and roundtable discussions and one in person field day. Outreach events are listed below: Seeds and breeding roundtable. Growing Stronger Conference. February 26, 2021. Attendance about 75. Midwest Seed Production and Plant Breeding Field Day, Riverbend Farm, Delano, MN, September 1, 2021. In-person attendance: 18. Views of virtual field day content: 858 (seed cleaning), 316 (SeedLinked), Participatory breeding projects (258) Plant breeding community of practice participants on Organic Seed Commons: 36 43 organic certifiers from most certifying organizations joined the organic certifier webinar. A survey was done before and after as well. SeedLinked 101 webinar. 45 attendees. (July 15th 2021) Trial Manager Webinar (August 17th 2021), 32 attendees SeedLinked growers info newsletter: Digging into trial results (read by 989 growers) It is Review Season: how to review with SeedLinked (read by 877 growers) Using SeedLinked community Feed (read by 833 growers) Use of check Variety (read by 1048) What do you plan to do during the next reporting period to accomplish the goals?Objective 1: We will continue with the development of the community of practice and outreach activities described in the grant narrative including webinars, videos, workshops, and field days. Objective 2: We will continue the development of SeedLinked functionality as described in the grant narrative, including the variety development process architecture, improvements to data sharing and data analysis capabilities, and trial design for breeding programs. Objective 3: We will continue with year two trials of the collaborative breeding case studies as described in the grant narrative, including greenhouse advancement over the winter, participatory trials in 2022 and selection with the independent breeders. **Impacts** What was accomplished under these goals? Objective 1: We developed the Seed Commons platform to host the community of practice and recruited participants to join the collaborative breeding community of practice. This includes email listserve functionality as well as many functions of social media platforms. We hosted an on-farm workshop at Riverbend Farm in August 2021, with farmer-breeder Greg Reynolds which featured the experimental lines from this project. In-person attendance at this field day was low, as it coincided with a rise in the COVID-19 Delta variant and people were hesitant to gather in person. However, we delivered virtual content for this field day via Instagram live, so that participants could ask questions and interact with guest speakers from afar. There were 3 instagram live sessions at the field day, one focused on Seedlinked and the breeding trials, one focused on seed cleaning equipment, and one focused on host farmer/ plant breeder Greg Reynolds. We hosted a roundtable at the Growing Stronger Organic Farming Conference in February 2021, (a joint virtual conference including MOSES and the Organic Vegetable Production Conference due to COVID). Objective 2: The SeedLinked platform now includes triadic design options as well as the option to set up a tasting trial. Full environment to communicate to R package has been build with Python Django API laying the ground for analytics. Native mobile apps have been developed and improved for android and iOS to allow farmers to enter data in offline mode and then upload data when reconnected to the internet. UX has been greatly improved. Integration of GIS USDA hardiness zone has been completed for USA. Trial results data sharing via public link was completed. An Internal Feed was built creating social group for each trial. Grower check functionality was built giving grower the choice to add any check in their trial. A notification framework was implemented under Firebase to create automatic reminder and prompt to drive engagement. The first stages of the variety development process architecture have been developed for early generation testing. We are working with the independent breeders and participants to refine this functionality including the ontology and line tracking across years, as well as the addition of larger testing networks for breeding material. We hosted a webinar and discussion for Organic Certifiers to provide information on how the SeedLinked platform can be used to help growers meet the organic seed requirement. A Beta Organic Seed Finder 2.0 has been built including 20 seed companies (Scraped) and filter by availability, organic and performance built. Finally, because the stability of platform is essential, a full new architecture was

implemented under Heroku, automatic tests were created under Sentry, Node Express API was cleaned and Azure events tracking was built to monitor and track all UX friction through the platform. Objective 3: We worked with breeders Keith Mueller and Erica Kempter to distribute early generation breeding lines to participating farmers. We had 36 participants in early generation tomato breeding (18 for each of two families) and 14 in an advanced tomato trial with an additional family. We also had 23 participate in the early generation pepper trial. We are growing out selections in the greenhouse over the winter to advance a generation and will send seed back to participants in the spring. **Publications** Organic Transitions (ORG)

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Pre-weaned Calf Rearing Options for Organic Dairy Systems

Accession No.	1023509
Project No.	MIN-02-G07
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Investigator(s)	Heins, B.; Endres, MA, I.
Performing Institution	UNIV OF MINNESOTA, ST PAUL, MINNESOTA 55108, PRE-WEANED CALF REARING OPTIONS FOR ORGANIC DAIRY SYSTEMS

NON-TECHNICAL SUMMARY

Our multidisciplinary team conducted advisory interviews and conducted research projects with organic dairy farmers, and we concluded that organic dairy producers are concerned about dairy calf rearing systems and the challenges with calf health in an organic production system to remain viable in the organic dairy industry. The present proposal addresses these challenges through research involving the University of Minnesota\'s West Central Research and Outreach Center\'s certified organic dairy and cooperating organic dairy farms in the region. The overarching goal of our project is to identify organic dairy calf rearing options that promote health and welfare in the organic livestock industry. We will develop methods to investigate the management feasibility of three alternative calf-rearing options: group housing in outdoor super hutches; pair housing of calves; and outdoor housing with the dam on pasture compared to traditional individual housing in outdoor hutches. We will also evaluate markers of calf health, behavior and welfare to ultimately provide recommendations on best calf rearing options for organic producers. Our stakeholder group of organic farmers helped identify and develop the objectives included in this proposal; and they will provide leadership for coordinated on-farm field research and sites for field days. The results of this project will be valuable to organic dairy producers, and will be disseminated to organic producers and industry representatives throughout the United States. Our research results will be shared with our larger stakeholder groups through field days, conferences, publications, and webinars.

OBJECTIVES

The long-term goal of this project is to enhance organic dairy production by improving organic dairy calf health and welfare. This overarching goal will be achieved by identifying the best calf housing options that give rise to positive calf welfare by performing a controlled research trial and on-farm studies. Specifically, we will 1)measure and evaluate markers of animal welfare outcomes of health, behavior, and emotional state of calves reared by: 1) individual housing (control); 2) pair housing; 3) group housing; and 4) with dam on pasture, 2)conduct on-farm benchmarking of health measures for each rearing option, and 3)determine the management feasibility through focus groups for each rearing option. The results of this project will be valuable to organic dairy producers, and will be disseminated to organic dairy producers and industry representatives throughout the United States. We willprovide recommendations on best calf rearing options for dairy producers to implement based on welfare outcomes, health benchmarks, and management feasibility.

APPROACH

The goal of this project is to identify organic dairy calf rearing options that promote animal welfare. This goal will be achieved by completing project objectives that include: 1) measure and evaluate markers of animal welfare outcomes of health, behavior, and emotional state of calves, 2) conduct on-farm benchmarking of health

measures for calf rearing, and 3) to determine the management feasibility through focus groups of calf rearing options. Data collected will be analyzed using models using the SAS Software (2019) for statistical analyses to obtain means and measurements of error. Models will be adjusted accordingly for each individual research study design. Pen and farm will be the experimental units for the study conducted at the WCROC and for the on-farm study, respectively. For data from calves housed together in pairs, the average of the 2 animals will be calculated, and this will be considered as a single observation. Because the data are means and the variance of a mean of n units is σ2/n, the number of calves per mean will be used as a weighting in the analysis (1 for individually housed calves, 2 for calves housed in pairs, 6 for calves housed in groups and dam-calf pairs). This makes the observations with heavier weight or higher precision more important than others, thus correcting for the imbalance of the design of individual versus group situations (Lensink et al. 2001). A repeated measures analysis will be performed to analyze measures taken more than 3 times on the same experimental unit (i.e. health scores, body weight, etc. for the experiment conducted at the WCROC). However, some measures may be aggregated into 1 measurement to simplify the analyses (i.e. health scores). For some measures (i.e. behavior and cortisol), data will be evaluated using non-parametric methods and logistic regression analysis. Categorical data obtained (i.e. focus groups, surveys, passive immunity success and failure) will be analyzed using a Chi Square test. Treatment means will be separated using multiple comparisons tests (e.g., Tukey or Bonferroni). Data analysis will be planned very carefully to consider all potential interactions and confounding effects. Seasonality and calf birth body weight and physiologic size could be a confounding factor in the analysis. These will all be adjusted for in the statistical analysis. To control for confounding in the analyses, we would either use Stratification and Multivariate methods. Stratification will allow us to fix the levels of confounders and make groups within which the confounder does not vary. Exposure-outcome association within each stratification of the confounder would be created, and therefore, the confounder cannot confound because it does not vary across the exposure-outcome. Stratified analysis works best in the way that there are not a lot of strata and if only 1 or 2 confounders must be controlled. Multivariate methods would be the more accepted form on statistical analysis if there are many potential confounders. Multivariate models can handle large numbers of covariates (and confounders) simultaneously. One method would be to use logistic regression to produce results that can be interpreted as an odds ratio. Logistic regression can control for numerous confounders. Odds ratios can be adjusted other covariates (including confounders). Another statistical analysis to consider is the Analysis of Covariance (ANCOVA) to control for potential confounding variables.For least squares means from ANOVA or ANCOVA, we can adjust the means for the observed marginal distributions of the variable rather than using equal coefficients across classification effects to determine the correct means adjusted for confounding and interaction effects.? Progress 09/01/20 to 08/31/24 Outputs Target Audience:We have reached organic dairy farmers across the United States. Information provide to farmers has been disseminated in print and and audio formats. We have also provided information from the project to veterinarians, organic dairy industry representatives across the United States on the calf housing proejct. We have also trained1 research scientistand 1 graduate student in experimental design and collection of research data. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project has trained organic dairy producers on the housing systems for pre-weaned dairy calves for organic production. Many extension educators and organic industry representatives were informed on housing systems and raising dairy calves at the Minnesota Organic Conference. We have also trained a graduate student in proper experiemental design, data collection, and analysis of data. Graduate stduents from Minnesota presented research on housing systems for organic produciton at the American Dairy Science Association meeting in June 2024 in West Palm Beach Florida. How have the results been disseminated to communities of interest?Over 1000 people have attended presentations related

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