

ORG Project Details

Award Year 2017

8 Research Projects

PROJECT INDEX

1. [Development of Effective Biological Control of Fire Blight for the Eastern United States](#) Grant No: 2017-51106-27001
2. [Perennial and Annual Organic Transition Systems to Optimize Soil Health, Carbon Sequestration, and Profitability](#) Grant No: 2017-51106-27000
3. [Breaking Barriers to Organic Swine Transition: Utilizing Cover Crops as Feed Ingredients to Reduce Feed Cost](#) Grant No: 2017-51106-27129
4. [Facilitating Improved Environmental and Soil Quality Through Increased Biodiversity and Crop/livestock Integration on Organic Farms](#) Grant No: 2017-51106-27007
5. [Harnessing the Voracity of the Biocontrol *Tyta Luctuosa* to Improve Management of Field Bindweed During Transition to Organic and Beyond](#) Grant No: 2017-51106-27004
6. [Transitioning to Organic Forage Cropping Systems, an Integrated Research, Education and Extension Project in Middle Tennessee](#) Grant No: 2017-51106-27003
7. [Introducing Organic to Producers of Grain-only and Pasture-grain Wheat Cropping Systems of Northern Texas.](#) Grant No: 2017-51106-27002
8. [An Ecological Approach to Disease Risk Management on Organic Poultry Farms.](#) Grant No: 2017-51106-27026

Development of Effective Biological Control of Fire Blight for the Eastern United States

Accession No.	1013444
Project No.	CONH655
Agency	NIFA CONH\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2017-51106-27001
Proposal No.	2017-03378
Start Date	01 SEP 2017
Term Date	31 AUG 2020
Grant Amount	\$459,978
Grant Year	2017
Investigator(s)	Zeng, Q.; White, JA, CH.; Sundin, GE, .; Yang, CH, .; Steven, BL, .
Performing Institution	CONNECTICUT AGRICULTURAL EXPERIMENT STATION, PO BOX 1106, NEW HAVEN, CONNECTICUT 06504

NON-TECHNICAL SUMMARY

Fire blight is a devastating disease of apples and pears. The termination of antibiotics in organic production requires alternative management options. Biological control represents an important group of organic management tools. Yet, none of the available biocontrols has provided consistent, high level of control against fire blight under humid climates in the Eastern U.S. We propose that the biocontrol candidates with the best efficacy in Eastern U.S. would be microorganisms isolated from apple stigmas under humid climates. In this proposal, we will perform the first comprehensive search and testing for bacterial and fungal biocontrol strains isolated from apple stigmas under humid climate in Eastern U.S. Using a combined approach of antibiosis screen, crab apple bioassay, and metagenomics, we will identify microorganisms with antimicrobial producing abilities and preemptive exclusion properties. In addition, we propose that using a mixture of strains with different antagonistic properties may provide better control efficacy than using individual strains. Meanwhile, field trials will be performed to evaluate the disease control efficacy of promising biocontrol strains identified from our preliminary search, along with new strains and strain mixtures identified from this study. Our extension/outreach activities include identifying factors that limit the expansion of organic pome fruit production in the Eastern U.S. and promoting organic production through plot demonstration, publications, and online presentations. This project addresses the ORG priority 3 \"Developing other allowable alternatives to antibiotics removed from NOP's list\".

OBJECTIVES

Objective 1: Establish a large collection of apple stigma colonizing microbes from Eastern U.S. Objective 2: Identify potential biocontrol agents from the apple stigma culture collection. Objective 3: Determine the control efficacy of the selected biological control candidates against fire blight in the field. Objective 4: Promote organic tree fruit disease management practices in Eastern U.S.

APPROACH

Methods:1.1 Flower collection Freshly opened flowers will be collected from 10 orchards, 5 orchards, and 2 orchards in Connecticut, Michigan, and Wisconsin respectively, from three popular apple varieties with different bloom time . A total of 30 flowers from three individual apple varieties will be collected, bagged in sterile Whilpak bags, placed on ice and brought to the respective laboratories for immediate processing on the same day. Environmental conditions including temperature, humidity and precipitation during collection period at each location will be documented. 1.2 Isolation of stigma associating microbes To characterize the stigma-colonizing microorganisms, the whole stigma with a portion of the supporting style will be dissected from the 30 flowers and placed in a sterile 1.5 ml microcentrifuge tube containing 1 ml of sterile potassium phosphate buffer (pH 7.0). Colonies with different morphology and growth characteristics will also be identified by amplification and sequencing of 16S ribosomal RNA genes. 20 fungal colonies from each plate will be preserved at -80 °C. Representative fungal colonies will be identified by amplification and sequencing of ribosomal large subunit (LSU) genes.2.1 Screen for antimicrobial producers. Microorganisms from the culture collection of apple stigma will be individually spotted on PSBM plates and incubated at 28°C for 48 h. Suspensions containing *E. amylovora* cells (104 CFU/ml) will be sprayed onto the plates with previously established stigma microbial colonies. The inoculated plates will be airdried and incubated for an additional 48 h at 28°C. The appearance of zones of inhibition around the stigma colonies indicates the production of antimicrobial compounds against *E. amylovora*.2.2 Screen for preemptive excluders. We will collect flower samples from different cultivars ('Braeburn', 'Granny Smith', and 'Fuji'), under different weather conditions (temperature and humidity), and at different geographical locations in Eastern U.S. (CT, MI, and WI). The stigma portion will be dissected, and used for microbial isolation as described in Objective 1. The microbial composition will be determined by 16S pyrosequencing. We will identify the most abundant, resilient, and prevalent species in Eastern U.S. (with 16S rRNA and LSU sequencing).2.3 Determine the efficacy of inhibiting *E. amylovora* growth on a crab apple flower bioassay. Isolates selected both as potential for preemptive exclusion and antibiosis will be tested for their ability to inhibit fire blight development on flowers through an in vitro crab apple flower bioassay. We will use a previously established protocol to acquire a year-round supply of crab apple flowers (Pusey, 1997). 2.4 Strain compatibility test and exploration of using strain mixture as biocontrol agents. We expect to have identified a suite of biocontrol strains with antimicrobial producing properties and/or preemptive exclusion activities. We will determine if strains with different modes of action are compatible to be used together in a biocontrol mixture.3.Field trials (Year 1-Year 3) will be performed at the Plant Pathology Research Farm at Michigan State University. A fire blight susceptible apple cultivar, 'Gala' will be used in the trials. In Year 1, a block of 28 trees will be used to test the fire blight control efficacy of the biocontrol strain BC250 identified in the preliminary work. Seven treatments, with 4 trees in each treatment, will include: 1. Water, 2. Streptomycin, 3. BC250 treatment at 50% bloom, 4. BC250 treatment at 80% bloom, 5. BC250 treatment at 50% and 80% bloom, 6. Bloomtime Biologicals (*P. agglomerans*), 7. Blossom Protect (*A. pullulans*). In Year 2 and Year 3, an additional 6 treatments (different biocontrol strains and strain combinations that show the best effect on crab apple flowers in Objective 2) will also be included. Strains that show the best biocontrol effect in Year 1 and Year 2 in Michigan will be selected to test at the Lockwood Farm of the Connecticut Agricultural Experiment Station in Year 3.4. We will promote organic fire blight management methods through a multichannel extension and outreach program. We will start by conducting grower surveys in MI, CT, and MA to identify current challenges of organic apple production in these regions. We then plan to identify the available solutions to these challenges and concerns, with a particular focus on disease management. We will gather the most recent knowledge from disease biology, organic management practices, breeding, cultivar disease susceptibility, and disease prediction models; integrating these to come up with plans to improve organic practices in the Eastern U.S. In addition to the current available knowledge, we also plan to generate new knowledge by conducting field research at our experimental farms to evaluate the efficacy of combinations of current available organic control options to accommodate the immediate needs of the growers.

PROGRESS

2017/09 TO 2020/08 Target Audience: Researchers in plant pathology, microbiology, horticulture, agronomy, extension educators, apple and pear growers, general public, policy makers Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? This project trained two postdoctoral scientists (Zhouqi Cui and Xiaochen Yuan), one technician (Cory Outwater), and 5 undergraduate students (Katelyn Miller, Sali Diallo, Zach Seltzer, Paul Sim, Courtney Haigler). 50% of them are female, 20% are African American. One student continued to pursue career in graduate school in plant related areas. How have the results been disseminated to communities of interest? Organic fire blight management practices were promoted and delivered to growers in the Northeastern U.S. through 1. extension publications, 2. webcast seminars, 3. grower meetings. Such efforts include two webcast seminars (one through Plant Management Network, 2016 and another one through Northeastern IPM Center IPM toolbox series), 2017 New England Vegetable and Fruit Conference, Four research presentations at the New England, New York, and Canada Fruit Disease and Pest Working Groups (Burlington VT, 2017, 2018, 2019, and virtually 2020), two

presentations at the Annual Meeting of APS (2017, 2020), on presentation at the Northeastern APS meeting (2020) an extension article on Fruit Notes. The PI also provided extension consultations, and delivered presentations to growers in Connecticut, Massachusetts, New Hampshire. Demonstration plots of organic treatments were also introduced to growers at the annual open house of the Connecticut Agricultural Experiment Station "Plant Science Day" (2017-2020). What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

IMPACT

2017/09 TO 2020/08 What was accomplished under these goals? A large collection of apple stigma colonizing bacteria consisting of more than 2800 bacterial isolates were obtained from orchards in New England in 2017-2018. The identity of the apple stigma colonizing bacteria was determined by using both cultural dependent and cultural independent methods. The majority of the isolates are Proteobacteria, with Enterobacteriaceae and Pseudomonadaceae being the dominant families. Identification of the most prevalent and abundant species contribute to future biological control testing. Cultural isolates are stored at -80 C freezer. Biological control potential of the apple stigma isolates was determined using both in vitro and in planta antagonistic assay against the fire blight pathogen *Erwinia amylovora*. Out of 1820 isolates tested, 380 isolates displayed strong inhibition against *E. amylovora* growth on LB agar plates. These bacteria belong to mostly to *Pseudomonas*, *Pantoea*, and *Stenotrophomonas* spp. Isolates were also inoculated to detached apple flowers and evaluated the antagonistic activities against *Erwinia amylovora*. Our results showed that at least 25 isolates effectively inhibited the growth of *E. amylovora* on detached apple flowers. Biocontrol agents with antagonistic potential against *E. amylovora* were further tested for its disease control efficacy in the orchard setting. Field experiments were designed and performed in Connecticut, Massachusetts, and Michigan from 2016-2019. Both single strain and strain mixture treatments were tested. 16S rRNA sequencing was used to monitor the impact of microbial treatment to the stigma microbiome on treated trees. Fire blight control efficacy of the biological controls was compared with conventional antibiotics and water control. Our results showed that compared to single strain treatments, strain mixtures with a *Pantoea* / *Pseudomonas* based formula not only more effectively reduced disease incidence, but also formed a more stable microbiome and reduced differences in microbiome between individual flowers. Organic fire blight management practices were promoted and delivered to growers in the Northeastern U.S. through 1. extension publications, 2. webcast seminars, 3. grower meetings. Such efforts include two webcast seminars (one through Plant Management Network, 2016 and another one through Northeastern IPM Center IPM toolbox series), 2017 New England Vegetable and Fruit Conference, Four research presentations at the New England, New York, and Canada Fruit Disease and Pest Working Groups (Burlington VT, 2017, 2018, 2019, and virtually 2020), two presentations at the Annual Meeting of APS (2017, 2020), on presentation at the Northeastern APS meeting (2020) an extension article on Fruit Notes. The PI also provided extension consultations, and delivered presentations to growers in Connecticut, Massachusetts, New Hampshire. Demonstration plots of organic treatments were also introduced to growers at the annual open house of the Connecticut Agricultural Experiment Station "Plant Science Day" (2017-2020). **PUBLICATIONS (not previously reported):** 2017/09 TO 2020/08 1. Type: Journal Articles Status: Published Year Published: 2020 Citation: Zeng, Q., Puawska, J., and Schachterle, J. (2020) Early events in fire blight infection and pathogenesis of *Erwinia amylovora*. *Journal of Plant Pathology* 2. Type: Journal Articles Status: Published Year Published: 2020 Citation: Cui, Z., Huntley, R., Zeng, Q., and Steven, B. (2020) Temporal and spatial dynamics in the apple flower microbiome in the presence of the phytopathogen *Erwinia amylovora*. *ISME Journal*. <<https://doi.org/10.1038/s41396-020-00784-y>>. 3. Type: Journal Articles Status: Published Year Published: 2019 Citation: Shidore, T., Zeng, Q., and Triplett, L.R. (2019) Survey of toxin-antitoxin systems in *Erwinia amylovora* reveals insights into diversity and functional specificity. *Toxins* 11:206 4. Type: Journal Articles Status: Published Year Published: 2019 Citation: Schachterle, J., Zeng, Q., and Sundin, G.W. (2019) Three Hfq-dependent small RNAs regulate flagellar motility in the fire blight pathogen *Erwinia amylovora*. *Mol. Microbiol.* 111: 1476-1492 5. Type: Journal Articles Status: Published Year Published: 2018 Citation: Steven, B., Huntley, R. B., and Zeng, Q. (2018) The influence of flower anatomy and apple cultivar on the apple flower phytobiome. *Phytobiomes Journal* (cover paper) 2:171-179 6. Type: Journal Articles Status: Published Year Published: 2018 Citation: Zeng, Q., Cui, Z., Wang, J., Childs, K. L., Sundin, G. W., Cooley, D. R., Yang, C.-H., Garofalo, E., Eaton, A., Huntley, R. B., Yuan, X., and Schultes N. P. (2018) Comparative genomics of *Spiraeoideae*-infecting *Erwinia amylovora* strains provides novel insight to genetic diversity and identifies the genetic basis of a low virulence strain. *Mol. Plant Path.* (cover paper) 19:1652-1666 7. Type: Journal Articles Status: Published Year Published: 2017 Citation: Patel, R. R., Sundin, G. W., Yang, C.-H., Wang, J., Huntley, R. B., Yuan, X., and Zeng, Q. (2017) Antisense peptide nucleic acid (PNA)-cell penetrating peptide (CPP) causes bactericidal effect in the fire blight pathogen *Erwinia amylovora*. *Front. Microbiol.* 8:687. 8. Type: Journal Articles Status: Published Year Published: 2019 Citation: Zeng, Q., Cooley, D.R. and Schultes, N. (2019) Evaluate Non-Antibiotic Management Options for Fire Blight. *Fruit Notes* 84:1-7 9. Type: Conference Papers and Presentations Status: Published Year Published: 2017

Citation: Zeng, Q., Schultes, N., and Cooley, D.R. (2017) Managing Fire Blight Under Humid Climate Conditions in Eastern United States. Proceedings for the New England Vegetable and Fruit Conference.

[↑ Return to Index](#)

Perennial and Annual Organic Transition Systems to Optimize Soil Health, Carbon Sequestration, and Profitability

Accession No.	1013546
Project No.	MIN-13-G32
Agency	NIFA MIN\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2017-51106-27000
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Start Date	01 SEP 2017
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Grant Amount	\$498,508
Grant Year	2017
Investigator(s)	Sheaffer, C. C.; Wyse, DO, .; Jungers, JA, M.; Grossman, JU, M.; Gutknecht, JE, .

NON-TECHNICAL SUMMARY

Although organic agriculture has more than tripled in production value over the last decade, the number of acres certified organic is still only 7% of total crop acreage nationally (USDA NASS). From our ongoing interaction with many stakeholders interested in transitioning to organic systems (Principles for Transitioning - NIFA Project #MIN-13-G27), we have learned that farmers are faced with unique production, environmental, and economic challenges. Production challenges include weed control, adapting to new crops and complex crop rotations, and nutrient management. In turn, these factors contribute to environmental and economic challenges during transition. One of the primary tenets of organic agriculture is improving soil health, but if concerns about potentially lower yields and lack of organic premium during the transition period are not addressed, growers will not be able to give high priority to environmental benefits when choosing a rotation strategy for transition. Our research seeks to expand transitioning producers' options beyond row crops to perennial crops so that they can fulfill the organic mandate to improve the soil, even before they are certified. As a result, farmers will not only benefit from increased profits in the short term, but their soil function will be improved, leading to higher yields over the long term. Improving the environmental and economic outcomes that farmers can achieve during organic transition would in turn foster greater adoption of organic practices. Regardless of how ecologically beneficial a practice is, producers cannot ignore economic realities in managing the three years of transition. Organic farming can be as profitable as conventional farming (Mahoney et al., 2004; Chavas, et al., 2009), part of which may be attributed to the price premiums that farmers receive for organic products (Archer et al., 2007; Clark and Alexander, 2010). Farmers considering transitioning to organic often anticipate economic returns based on yields typically attained using conventional practices, while in fact, yields often decrease during transition, likely due to limiting N, weed pressure, and farmer inexperience with a new production system (Delbridge et al., 2015; Martini et al., 2004). Transitional crops cannot be marketed and sold as organic, therefore the price premiums that come with organic products are not available to offset the economic losses related to lower yields. These and other factors can lead to lower returns in transition (Dabbert and Madden, 1986). A recent study of organic and transitioning Minnesota farmers found that profitability for transitioning farmers fell dramatically in transition (Delbridge et al., 2015). Among the significant problems these same farmers experienced were lower yields and reduced fertility, and complications due to weeds (King et al., 2014). This clearly demonstrates the many risks farmers experience during transition and may also explain why some conventional producers choose not to convert to organic. We are proposing to examine transitioning rotation options - including a novel perennial grain crop - that may address both environmental and profitability concerns. Now is a critical time for this research

because of low commodity prices that translate to difficult profit margins during transition, and current trends of declining organic prices due to imports from foreign nations (Bunge, 2017).

OBJECTIVES

Farmers interested in transitioning from conventional to organic systems are faced with unique challenges regarding weed control, fertility, improving soil health, and generating income during the transition period. Many transition systems rely on tillage to control weeds and annual crop rotations, which have been associated with soil carbon (C) loss. Intermediate wheatgrass (IWG) is a cool-season grass that is being bred for increased seed yields to become the first perennial grain crop. IWG could help producers overcome the challenges of organic transition, while also simplifying management, reducing tillage-associated C emissions, and improving soil health relative to annual crop-based organic transitions. This project will compare six organic transition systems that include IWG, summer and winter annuals, perennial legumes, and systems with various combinations of grain, forage, and cover crops. In each system, we will measure 1) agricultural output/profitability, 2) soil health (both biological and physical integrity), 3) C dynamics, and 4) weed suppression. Our objective is to identify an organic transition cropping system that improves profitability, soil health, and C sequestration. Crop yields will be incorporated into enterprise budgets to determine profitability of each system. This project is driven by research and outreach that documented concerns of Midwestern farmers regarding reduced fertility and yields, complications due to weeds, and low profits during organic transition. Results will be shared through Extension and other outreach efforts. This project supports the Organic Transitions program's goal of increasing the competitiveness of transitioning farmers. The following is an overview of the proposed treatments: Transition system 1: Transition system 1 is a monoculture stand of the perennial grass IWG that will be fertilized with an organic N source, be harvested annually for grain, and then harvested to remove residual straw annually. This system will be tilled during the last year of the transition just prior to planting the corn/soybean crop and will provide winter cover for all three years of the transition period. Transition system 2: Transition system 2 is an intercropped bi-culture of intermediate wheatgrass and alfalfa where the IWG will be harvested for grain and the alfalfa will function as a green manure for N fertility. Alfalfa could also affect C cycling by increasing N content of litter inputs, and reduce weed competition by increasing ground cover. This system will be tilled during the last year of the transition just prior to planting the corn/soybean crop and will provide winter cover for all three years of the transition period. Transition system 3: Transition system 3 is an alfalfa monoculture. Organic alfalfa is a valuable commodity for the rapidly growing organic dairy industry (Greene and McBride, 2015), and therefore is one of the more important organic crops for farmers in the Upper Midwest. Alfalfa does not require N fertilizer or annual tillage, which improves the carbon footprint of this system. This system will be tilled during the last year of the transition as described in system 2. Transition system 4: This system includes a rotation of forage/green manure and high-value food crops including summer and winter annuals and a perennial. The perennial forage crop red clover is frost seeded into winter wheat and then overwinters between the first and second year, therefore preventing two tillage events. Red clover is followed by a high-value, food-grade soybean that is eligible for a non-GMO premium, even during transition (Kowalski, 2017). This system includes both grasses and legumes during different periods of the transition, and will require two tillage events and provide winter cover for all years during the transition. Transition system 5: This system is a commonly used corn/soybean rotation with a mixture of hairy vetch and winter rye as a winter cover crop. The system will require annual tillage, which may reduce the C storage potential, but will provide winter cover to conserve topsoil and its role in C sequestration. Transition system 6: This system includes a rotation of corn and soybeans managed without a winter cover crop. This treatment serves as a check as it is a common non-organic rotation in the Upper Midwest.

APPROACH

Duplicate transition experiments using the treatments described above will be conducted at two contrasting transitioning sites in Minnesota. One site will be located in west-central MN at Madison (45.00 °N, -96.15 °W) on a Webster Clay Loam. The second site will be located on a Waukegan silt loam near Farmington (44.64 °N, -93.14 °W) in south-central MN. Average annual rainfall at Madison and Farmington is 45 and 70 cm, respectively. Each site is currently conventionally farmed. Sites will be selected so that phosphorus, potassium, or other nutrients are not limiting. The experimental design for each experiment is a randomized complete block with four replications. In the third year of the experiment, we will employ a split-plot design by establishing corn and soybean following each of the main transition systems. Each plot will be 12 x 20 m. Intermediate wheatgrass, alfalfa, winter wheat, and winter rye-vetch cover crops will be seeded in September 2017, while other crops will be seeded in May 2018. At both locations, the crop in the season preceding the experimental period will be spring-seeded wheat that will be harvested for grain by mid-August 2017. We will use organically produced IWG seed and commercially available crop varieties. In spring of 2020, each plot will be divided into two 6 x 20 m

subplots for seeding of corn and soybean. In all experiments, plant nutrients (P, K, S, and B) will be supplied to non-limiting levels using composted manure as recommended for each species based on early spring soil testing in 2017. Soil pH will be adjusted as necessary according to Minnesota recommendations. For IWG and corn monocultures, N fertilizer will be applied in April of 2018 and 2020 using composted poultry manure. Weed assessment: The population density and biomass of weed species will be assessed in spring of 2018, 2019 and 2020 at two and four weeks after seeding of annual crops before each tillage by sampling four 0.5 m² areas within each plot along the center rows of each plot. We will use the same timing for the weeds in the perennial crops. We will also measure weed seedbank in fall 2017 and in spring of 2020 in early May before the first tillage using a sampling procedure adapted from Forcella (1992). Carbon budget: The carbon budget of each cropping system will be calculated using a comprehensive analysis of carbon inputs and outputs from the system, as described by Cheng et al. (2000), but modified for measurements appropriate for our field scale agronomic system. We will calculate both flux-based and pool-based carbon budgets. Carbon inputs: The flux based calculation compared to the pool based calculation will give us an understanding of variation in the carbon budget over each growing season versus the total C sequestration per growing season. GPP flux will be determined with leaf area index measurements made every three weeks throughout the growing season using a portable LI-COR 6400. ANPP will be determined by measuring the dry matter yield and C content of each crop, plant litter, or other living residue, before crop termination. These aboveground biomass components will be measured from 3 randomly sampled 0.5 by 0.5 m quadrats in each plot for all crops within all systems. BNPP will be determined using a 90 cm deep soil core 4 cm in diameter that will be evacuated from each quadrat immediately after aboveground sampling. The three cores will vary in proximity to plant crowns; one adjacent to crowns, one in the center of the inter-row space (furthest distance from crowns), and one in between. Total root biomass will be separated and processed using the methods described for the root ingrowth cores below. All above- and belowground biomass will be dried, weighed, ground, and analyzed for C and N using a combustion analyzer (Jungers et al., 2017b). A second more detailed measurement of BNPP will be measured annually at the beginning and end of all annual crop phases, and during the spring, summer, and fall of all perennial transition systems. We will use root ingrowth cores to determine BNPP following the methods described by Steingrobe et al. (2001). Carbon outputs include measurement of CO₂ and CH₄ emissions every three weeks in each plot throughout the growing season (Venterea et al. 2005), using a Gasmeter gas flux analyzer available. Soil biological and chemical properties: Soil carbon-related data will include measures of various carbon (C) and nitrogen (N) pools to help understand nutrient cycling and C accrual under each system at each site. Abiotic measurements of soil C include permanganate oxidizable C (POX-C) and dissolved C and N (DOC, DON). The POX-C pool of soil C is a highly active and labile pool of C that is known to be sensitive to management changes due to its accessibility to soil microbes, and thus likely to be a predictor of long-term soil C storage. Because microbial growth and activity strongly mediate nutrient cycling and either accumulation or degradation of soil C, we will measure microbial biomass, microbial enzyme activities (decomposition potential), and soil respiration, to determine soil C gains and losses of CO₂ to the atmosphere. Soil physical properties: Soil infiltration, aggregate size, and stability are important physical properties that mediate C dynamics. These metrics will be measured in spring of year 1 and fall of year 3 of the study using the methods advised by the NRCS (Soil Quality Institute, 2001). We will also measure soil bulk density using the core method (Blake and Hartge, 1986) at the beginning and end of the study in each transition system in order to express soil C on a mass basis. Statistical analysis: Data will be analyzed using suitable modern parametric and non-parametric methods based on the distributions they follow. Most response variables will be analyzed by location. When appropriate, location will be treated as a fixed effect and tested alone and as an interaction with treatments to determine if treatments affect soil and yield variables similarly across locations. In response to the American Statistical Association's recent published statement on the use of P-values (Wasserstein and Lazar, 2016), we will use a combination of confidence and prediction intervals, in conjunction with P-values, to determine statistical significance of our University of Minnesota Project findings. A priori comparisons of yields across treatments will be made using analysis of variance within years. For example, we will compare IWG grain yields in transition system 1 and 2 for each year to test the effect of alfalfa on IWG grain yield. Yield data will also be used in economic analyses. Soil data analysis: Some soil variables - such as total organic C, bulk density, particle size distribution, and mineral concentrations - will be measured once in the beginning of each transition system and once at the end. We will compare the change in these variables across transition treatments to account for any initial spatial variation. Other soil data - such as POX-C, microbial C, and root biomass, will be measured annually. Comparisons will be made both within and between years among treatments using analysis of variance. We will test for time related trends in annually measured variables within each treatment using time-series analyses, with methods that account for potential autocorrelation in both space and time. Crop enterprise budgets: To aid in producers' financial understanding of the rotation treatments we are comparing, we will create crop enterprise budgets using the recommended standard practices for generating costs and returns estimates (American Agricultural Economics Association Task Force, 2000). Crop enterprise budgets include revenue (product revenue and government payments) and costs (seed, organic fertilizer, machinery operation costs, labor, management, rent

and insurance) to generate net returns per acre (Lazarus, 2015; Chase and Delate, 2015). **Progress** 09/01/17 to 08/31/21 **Outputs** Target Audience: Nothing Reported Changes/Problems: COVID 19 significantly affected our ability to interact with organic producers and other clientele. Therefore our extension education program is behind schedule. Because our results will have impact on the organic agricultural community, we expect to make presentations at producer and professional meetings. We will also develop extension education publications. What opportunities for training and professional development has the project provided? Training of undergraduates and Post Doc How have the results been disseminated to communities of interest? Results were presented at the Iowa Learning Farms webinar series on July 21, 2021 "Improving Soil Health with a Novel Perennial Grain Crop" What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? Six transitional cropping system treatments were established beginning in 2017 at St. Paul, Rosemount, and Lamberton, MN. St. Paul and Rosemount have silt loam soils while Lamberton has a loam soil. Cropping systems were an alfalfa monoculture (ALF); a monoculture of intermediate wheatgrass (IWG), an intercropped bi-culture of IWG and alfalfa (IWGalf); a corn/soybean rotation with a hairy vetch-winter rye cover crop (SoyCCorn); a soybean corn rotation (SoyCorn); and winter wheat with interseeded red clover (WheatRC). Following two years of the transitional cropping systems, corn and soybean were grown as split plot treatments in 2020. During the two year transition, total biomass of IWG and IWGalf was higher than other cropping systems but grain production was highest in SoyCorn and SoyCCorn. In 2019, total biomass of ALF and RC was the least while grain yield highest in for SoyCorn. Cropping systems were compared by measuring caloric production during transitioning by converting biomass dry mass to GCal/ha. IWGalf produced the highest amount of calories at St. Paul, but these were similar to the SoyCorn at Rosemount and Lamberton. ALF and WheatRC and IWG were among the lowest in caloric production at all locations. Corn and soybean grain and stover yields in the third year (2020) of transitioning was affected by a location by cropping system interaction. Corn grain and stover yields were similar following all transition crops at St. Paul, but at Rosemount and Lamberton they were lower in the SoyCCorn than for the other transition crops. ALF resulted in lower soybean grain and stover yields at St. Paul and Rosemount but yields were similar for the other systems. IWG reduced the weed pressure in subsequent corn and soybean crops at St. Paul but transition crops had no effect on weed counts at other locations. Cropping systems affected many of the variables measuring soil health. Cropping systems affected soil pH at two of the three sites. IWG and SoyCorn and SoyCCorn generally had higher pH than ALF, WheatRC, and IWGalf. Corn sub-plots had higher pH than soybeans at all sites in Fall 2020. Cropping systems affected soil N content only at St. Paul where the SoyCorn had lower soil N content than all other treatments while IWGalf had the highest soil N. Cropping systems had no effect on soil P content at any site and inconsistent effects on soil K content. Cropping systems affected root biomass at all sites and there was a significant interaction between cropping system and depth. IWG or IWGalf had the highest while SoyCorn had the least amount of root biomass across site-years. Root biomass differed among depths cm with the highest root biomass found at 0-15 cm. IWG and IWGalf improved soil physical properties such as aggregate stability and sorptivity whereas bulk density was similar among all treatments after two years transitional cropping. Such findings illustrate that IWG can improve soil parameters crucial for water management and soil erosion in the short term which could further act as a building blocks to store C and improve environment quality in the long term. Cropping system treatments did not change the soil microbial biomass C or microbial extracellular enzyme activities or water infiltration at any sites during the two-year experimental period. **Publications** **Progress** 09/01/19 to 08/31/20 **Outputs** Target Audience: Nothing Reported Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Training has been provided in field research techniques and in laboratory analysis of soil health parameters. These training opportunities have been provided to 2 undergraduate students, 2 technical staff and 1 post-doctorate person. How have the results been disseminated to communities of interest? Opportunities to disseminate research results at producer field days have been diminished in 2020 because of COVID-19 restrictions. We do report presentations at a conference in fall of 2019, a virtual grower field day, and a presentation at a local college. What do you plan to do during the next reporting period to accomplish the goals? Completion of statistical analysis of yield and soil health data. **Impacts** What was accomplished under these goals? We evaluated the 2-yr cumulative effect of six annual and perennial cropping systems on soil health in Fall 2019. A comprehensive soil sampling was conducted to measure soil physical, chemical, and biological properties. In Fall 2019, Kernza systems had about seven times more root biomass than corn-soybean annual systems. Increased root input and less disturbance in Kernza systems resulted in higher mean weight diameter of soil aggregates as compared to other cropping systems. We also observed an increase in infiltration rate by 2.5 times in Kernza system than corn-soybean at one of the three sites likely due to improved soil structural quality. We did not observe any changes in soil compaction and water storage to a 60 cm soil depth. Among the soil chemical properties, a decrease of pH was observed in alfalfa systems by 0.15 to 0.28 units as compared to Kernza and annual systems. The observed change in pH was likely due to differences in root activity and N uptake mechanisms among cropping systems. At two of the three sites, Kernza treatments had 47 to 129 ppm more potassium in 0-15 cm soil depth as compared

to alfalfa and wheat-red clover systems. Total carbon, labile carbon, available nitrogen, and phosphorus were similar among treatments. We observed no changes in total microbial biomass among treatments but Kernza tended to increase biomass of certain microbial groups. Kernza significantly increased gram negative bacteria and actinomycetes compared to annuals. Overall, Kernza systems appeared to outperform other annual and perennial cropping systems in maintaining soil health. Results indicate that Kernza may not be able to increase total soil C or microbial biomass in the short term but it can strengthen the building blocks of soil (e.g. aggregates) to optimize soil health in the long run. In Fall 2019-Spring 2020, the six cropping systems were terminated by disking and field cultivation for preparing a good seed bed. We planted soybean in one half and corn in other half of each plot in spring. Weed and crop yield data has been collected and statistical analysis is being conducted to determine treatment effects. Soil samples are undergoing lab and statistical analysis to determine the legacy effect of each cropping system. **Publications** - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Rakkar, M.K., C. Sheaffer, J. Jungers, J. Gutknecht, J. Grossman, F. Li. 2019. Optimization of soil health with a novel perennial grain crop. ASA-SSSA-CSA International Annual meeting-2020.

PROGRESS

2017/09 TO 2018/08 Target Audience: Our target audience will be conventional producers interested in transitioning, organic producers, agricultural researchers, Extension educators and sustainable agriculture outreach organizations. We will partner with University of Minnesota Extension and Green Lands Blue Waters to transfer research results from this project and our other projects to producers and organic advisers. These materials will have dual functions: to support conventional growers looking to transition and to assist organic growers with an interest in intermediate wheatgrass production. All our resources and publications will be accessible through Minnesota Extension (<http://www.extension.umn.edu/>), the Green Land Blue Waters (<http://greenlandsbluwaters.net/>), and ForeverGreen Initiative (<http://www.forevergreen.umn.edu/>) websites, and our own web site (<http://www.sustainablecropping.umn.edu/>). Stakeholder groups. From our previous and current projects (Tools for Managing Risks - RMA Partnership #051E08810211, Principles for Transitioning - NIFA Project #MIN-13-G27, and others), we have existing organic and transitioning stakeholders in Minnesota with whom we have regular contact. Through this proposed project's outreach, we will continue to meet not only with these farmers, but with other new farmers interested in this new project. We anticipate strong demand for our events, as there currently is great interest in transitioning. For example, more than 200 people from six states have attended our transitioning workshops so far. Green Lands Blue Waters has been collecting and organizing farmer inquiries regarding IWG, and will be co-hosting a field day in summer 2017 to showcase this new crop to farmers, endusers, local and state land managers, and other relevant stakeholders. The outreach events for the proposed project will be developed using lessons learned from these upcoming events. On-farm Field Days. Field plot tours for producers, researchers, educators and nongovernmental personnel will be held at each research site at least once during the grant period. Producers who conduct on-farm research will participate and provide their insights on the research. Our goal will be for 40 people to attend each on-farm demonstration event. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? A new post-doctoral researcher has joined the team to work on this project, providing her with laboratory training for soil analyses related to this project. How have the results been disseminated to communities of interest? Yes, preliminary results and a description of the project has been reported to various stakeholder groups at three field days that occurred in August, 2018. What do you plan to do during the next reporting period to accomplish the goals? We plan to continue collecting data as outlined in the proposal. Initial data analysis will be conducted before the next progress report. Initial results will be presented at conferences before the next progress report.

2018/09 TO 2019/08 Target Audience: Our target audience will be conventional producers interested in transitioning to organic, organic producers, agricultural researchers, Extension educators and sustainable agriculture outreach organizations. We will partner with University of Minnesota Extension and Green Lands Blue Waters to transfer research results from this project and our other projects to producers and organic advisers. These materials will have dual functions: to support conventional growers looking to transition and to assist organic growers with an interest in intermediate wheatgrass production. All our resources and publications will be accessible through Minnesota Extension (<http://www.extension.umn.edu/>), the Green Land Blue Waters (<http://greenlandsbluwaters.net/>), and ForeverGreen Initiative (<http://www.forevergreen.umn.edu/>) websites, and our own web site (<http://www.sustainablecropping.umn.edu/>). We also are interacting with state legislators and the Governor of Minnesota as well as major corporations that are interested in using Kernza grain and for sustainable marketing. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? advanced training in laboratory analysis of soil health parameters and

green house gas fluxes. How have the results been disseminated to communities of interest? We conducted two field days that transferred results of our research to producers. These occurred at Lamberton and Morris Minnesota. Kernza®: A new perennial grain crop for organic transition and forage production. Organic Field Day on July 10, 2019. Southwest Research and Outreach Center, Lamberton; Organic Grazing Field Day on 13 August 2019. In addition, we held tours at St. Paul in which small groups of individuals from major companies attended. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

2019/09 TO 2020/08 Target Audience: Nothing Reported Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Training has been provided in field research techniques and in laboratory analysis of soil health parameters. These training opportunities have been provided to 2 undergraduate students, 2 technical staff and 1 post-doctorate person. How have the results been disseminated to communities of interest? Opportunities to disseminate research results at producer field days have been diminished in 2020 because of COVID-19 restrictions. We do report presentations at a conference in fall of 2019, a virtual grower field day, and a presentation at a local college. What do you plan to do during the next reporting period to accomplish the goals? Completion of statistical analysis of yield and soil health data.

IMPACT

2017/09 TO 2018/08 What was accomplished under these goals? The experiment was successfully established in fall of 2017 at three locations in Minnesota; St. Paul, Rosemount, and Lamberton. Prior to planting crops, soil samples were collected and analyzed for background physical and chemical parameters. For the perennial crops (systems 1, 2, and 3) crops were planted in fall of 2017 and successfully survived the winter. Cover crops were planted in fall of 2017 for systems 5 and 6 and successfully survived the winter. Biomass yields were collected at all relevant time points, as well as soil sampling for various soil health metrics. Soil greenhouse gas emissions data were collected throughout the growing season. **PUBLICATIONS (not previously reported):** 2017/09 TO 2018/08 No publications reported this period.

2018/09 TO 2019/08 What was accomplished under these goals? We continued an experiment to evaluate the impact of annual and perennial cropping systems on soil health and to compare the profitability of different systems during the organic transition period. Data collected for each of the treatments: In 2018, annuals yielded more total aboveground biomass than perennials at harvest. Among perennials, alfalfa had the highest total biomass production ranging from 2.02-9.11 Mg/ha whereas monocultured Kernza had the least yield ranging from 0.98-1.23 Mg/ha. Among annuals, total wheat yield ranged from 5.17-8.68 Mg/ha whereas soybean and soybean-cover crop treatments had similar total biomass production ranging from 5.38-7.66 Mg/ha. Belowground biomass (roots) was more for perennials than annuals. For example in Fall 2018, averaged across three sites, Kernza produced 16 times more root biomass than soybean systems which shows the potential of perennials to input more C into the soils. However, no significant differences were observed in labile carbon pool in Fall 2018 and Spring 2019 among treatments. Annual systems such as soybeans showed higher total inorganic N during Fall 2018 as compared to perennials. The increased amount of nitrogen in soils is more likely to be leached and increase nitrate levels of ground water. We observed similar results of higher total inorganic N in soybean systems during spring 2019 as well. Annual systems also showed increase in soil compaction at one of the site during spring 2019 potentially due to more machinery traffic as compared to perennials. No significant differences were observed in enzymatic activity at any location during Fall 2018. In Fall 2019, a more comprehensive soil sampling was done to monitor any changes in soil health and carbon budget due to different cropping systems. In fall of 2019, we also conducted tillage across all treatments in preparation for planting corn and soybean in spring of 2020 **PUBLICATIONS (not previously reported):** 2018/09 TO 2019/08 1. Type: Conference Papers and Presentations Status: Accepted Year Published: 2019 Citation: Rakkar, M.K., C. Sheaffer, J. Jungers, J. Gutknecht, J. Grossman, F. Li. 2019. Impact of perennial and annual organic transition systems on profitability and soil health indicators. ASA division: Global Agronomy. ASA-SSSA-CSA International Annual meeting-2019, San Antonio, TX. 2. Type: Conference Papers and Presentations Status: Accepted Year Published: 2019 Citation: Rakkar, M.K., G. Bergquist, C. Sheaffer, J. Jungers, J. Gutknecht, J. Grossman. 2019. Kernza soil health benefits. Fourth International Kernza Conference Madison, Wisconsin, USA.

2019/09 TO 2020/08 What was accomplished under these goals? We evaluated the 2-yr cumulative effect of six annual and perennial cropping systems on soil health in Fall 2019. A comprehensive soil sampling was

conducted to measure soil physical, chemical, and biological properties. In Fall 2019, Kernza systems had about seven times more root biomass than corn-soybean annual systems. Increased root input and less disturbance in Kernza systems resulted in higher mean weight diameter of soil aggregates as compared to other cropping systems. We also observed an increase in infiltration rate by 2.5 times in Kernza system than corn-soybean at one of the three sites likely due to improved soil structural quality. We did not observe any changes in soil compaction and water storage to a 60 cm soil depth. Among the soil chemical properties, a decreased of pH was observed in alfalfa systems by 0.15 to 0.28 units as compared to Kernza and annual systems. The observed change in pH was likely due to differences in root activity and N uptake mechanisms among cropping systems. At two of the three sites, Kernza treatments had 47 to 129 ppm more potassium in 0-15 cm soil depth as compared to alfalfa and wheat-red clover systems. Total carbon, labile carbon, available nitrogen, and phosphorus were similar among treatments. We observed no changes in total microbial biomass among treatments but Kernza tended to increase biomass of certain microbial groups. Kernza significantly increased gram negative bacteria and actinomycetes compared to annuals. Overall, Kernza systems appeared to outperform other annual and perennial cropping systems in maintaining soil health. Results indicate that Kernza may not be able to increase total soil C or microbial biomass in the short term but it can strengthen the building blocks of soil (e.g. aggregates) to optimize soil health in the long run. In Fall 2019-Spring 2020, the six cropping systems were terminated by disking and field cultivation for preparing a good seed bed. We planted soybean in one half and corn in other half of each plot in spring. Weed and crop yield data has been collected and statistical analysis is being conducted to determine treatment effects. Soil samples are undergoing lab and statistical analysis to determine the legacy effect of each cropping system. ****PUBLICATIONS (not previously reported):**** 2019/09 TO 2020/08 Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Rakkar, M.K., C. Sheaffer, J. Jungers, J. Gutknecht, J. Grossman, F. Li. 2019. Optimization of soil health with a novel perennial grain crop. ASA-SSSA-CSA International Annual meeting-2020.

[↑ Return to Index](#)

Breaking Barriers to Organic Swine Transition: Utilizing Cover Crops as Feed Ingredients to Reduce Feed Cost

Accession No.	1013571
Project No.	MIN-02-G04
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Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2017-51106-27129
Proposal No.	2017-03376
Start Date	01 SEP 2017
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Grant Amount	\$245,976
Grant Year	2017
Investigator(s)	Li, Y.

NON-TECHNICAL SUMMARY

In contrast to dramatic growth in other sectors of organic production, organic pig production declined by 6% from 2008 to 2014. The most significant barrier to organic swine transition is high feed cost, which contributes 65-70% of total production cost. This project aims at utilizing winter camelina (a cash cover crop) press cake to reduce feed cost. Specific objectives are to: 1. Determine the optimal amount of camelina presscake as a feed ingredient for pigs; 2. Grow organic camelina in a double-crop system with soybeans and evaluate its impact on yield, cost, and return; 3. Determine effects of dietary camelina presscake supplementation on growth performance and meat quality of pigs that are raised under near-organic conditions. Field trials will be conducted on the university's organically certified land. Animal trials will be conducted in a bedded, alternative housing system with pigs fed organic feed according to NOP standards. Economic analysis and lifecycle assessment will be conducted to compare two swine-cropping systems with and without camelina integration. This project will utilize a systems-approach to address barriers to organic swine transition (Priority 4) and will also contribute to Priority 1. Through field days, workshops, seminars, online materials, and publications, results will be disseminated to end-users. By reducing feed cost and documenting environmental and economic impacts of cover crops on organic pig production, this project is expected to increase the number of organic pig farmers and the number of pigs raised organically.

OBJECTIVES

The long-term goal of this project is to increase and sustain organic swine production through breaking barriers to organic swine transition. We will attempt to break the barrier by utilizing presscake of cash cover crops as an alternative feed ingredient to partially replace corn and soybean meal in diets for organic pigs. The specific objectives are to evaluate the optimal supplemental amount of camelina presscake as an alternative feed ingredient for pigs; to grow organic camelina in a double-crop system with soybean and evaluate its impact on total yield and cost return; to determine effects of dietary camelina presscake supplementation on growth performance and meat quality of pigs that are raised under near-organic conditions; and conduct an economic analysis and life cycle assessment of two organic swine-cropping systems with and without camelina integration.

APPROACH

We will evaluate the potential of camelina presscake as alternative feed ingredient for pigs. This study will be conducted at the West Central Research and Outreach Center (WCROC) Swine Unit. Pigs (n = 240, balanced for sex, initial weight = 25 kg) in 30 pens (8 pigs/pen, 4 barrows and 4 gilts) will be used. Six pens of pigs will be assigned randomly to one of the five dietary treatments: 1) Control (basal diet, 0% supplementation of CPC); 2) 2% supplementation of CPC to the basal diet (2% CPC); 3) 5% supplementation of CPC (5% CPC); 4) 10% supplementation of CPC (10% CPC); and 5) 15% supplementation of CPC (15% CPC). Meat quality will be examined. From each treatment group, 6 pigs balanced for sex with body weight close to 110 kg will be harvested at the Andrew Boss Laboratory of Meat Science (ABLMS) at the University of Minnesota, St. Paul. At 24 h postmortem, carcasses will be evaluated for 24 h pH, cold carcass weight, first and tenth rib back fat, carcass length, loin eye area, loin eye subjective color score, loin eye objective colorimeter (L^{*}, a^{*} and b^{*}) and loin eye marbling score. Carcasses will then be fabricated according to North American Meat Purchasing Specifications into wholesale cuts and each portion weighed for fabrication percentage. Loin chop sensory evaluation will be conducted by University of Minnesota Department of Food Science and Nutrition within the Sensory Center according to ASMA guidelines (ASMA, 1995). To evaluate the feasibility of producing camelina for organic swine feed, 10 acres of organic certified land at the WCROC will be used to plant camelina in the fall of 2018. Joelle winter camelina seeds will be supplied by the research team at the USDA-ARS Soil Lab. Winter camelina will be seeded after corn harvest in mid-October with a grain drill at 9 kg ha⁻¹. Times, durations, and inputs for all aspects of management for the corn, camelina, and relayed-soybean will be recorded and compared to those performed for an equivalent cropping portion of the control field in a standard organic corn-soybean rotation for the same period. These data, along with crop yields, will allow economic analysis of the winter camelina system compared to a traditional organic system. Based on results of trial 1 for objective 1, treatment diets using CPC to replace corn and soybean meal will be formulated for growing-finishing pigs. Since growing-finishing pigs consume most feed (approximately 350 kg/pig for the entire period) compared to pigs during other production stages, they are the target for feed savings. The diets will be formulated to meet nutritional requirements for pigs according to NRC (2010) recommendations. While the inclusion amount of camelina in the treatment diet will be determined based on the results of trial 1, for the purpose of planning animal trials, at this point we propose 10% supplementation level based on previous research. We will use input and output data (input: labor, seed, machine time, feed, bedding, medication for pigs treated and sold as conventional pork, facility depreciation, and utility utilization; output: yield, the number of pigs and carcass weights sold for organic pork and for conventional pork, respectively, revenue from culled animals) generated from the field research to develop crop and livestock enterprise budgets for the organic corn and soybean main crops with and without the camelina cash-cover crops. Enterprise budgets will be used to organize yield, price, and cost information to compare profitability in order to suggest which crops and practices producers should adopt and likely will adopt over time. Data from the agronomic and livestock systems components of this project will be used to conduct a life cycle assessment (LCA) of organic pork production with camelina as a feed ingredient, which will focus on the environmental impacts of this alternative organic ingredient. The specific impacts examined will include fossil energy use, greenhouse gas emissions, and land use, which are important considerations in sustainable farming systems. ****Progress**** 09/01/17 to 08/23/21 ****Outputs**** Target Audience: The target audience for this project is existing and potential organic farmers, their stakeholders, researchers, and agricultural professional. Final results of the project have been communicated with the audience through publications. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? During this reporting period, the project provided an opportunity for the PD to present results of the project at a national conference. Over the grant period, the project has provided opportunities for a graduate student and a visiting scholar to be trained in organic pig research, and for the PDs to collaborate with agronomists, soil scientists, applied economists, and environmental scientists to tackle tough issues in organic pig production. The project also provided opportunities for the PDs and the investigators to attend organic conferences and to interact with organic farmers. All these opportunities enhanced the professional development of the PDs and the investigators, and supported training of graduate students, undergraduate students, and organic farmers. How have the results been disseminated to communities of interest? During this reporting period, final results have been compiled into manuscripts for publications in peer-reviewed journals, and partial results were presented at the ASAS (American Society of Animal Science) National Conference. Additionally, a white paper of life cycle assessment on integrating camelina into organic pig production is in preparation for online publication. Over the grant period, available results were disseminated to organic farmers, pig producers, and communities of agriculture through publications and presentations. Articles related to this project were published in social media, newsletters, and newspapers. 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 most significant barrier to organic swine transition is high feed cost, which contributes 65-70% of total production cost. This project investigated whether growing winter camelina as a feed ingredient could reduce feed cost and increase financial returns for organic pig farmers through a system-approach. The project has been successfully completed and has generated 15 extension articles and abstracts; 13 presentations at conferences, seminars, and stakeholder meetings; and 4 manuscripts

for peer-reviewed journals (three published or submitted, and one in preparation). Five field-days and two workshops have been organized to deliver findings of the project and related information to stakeholders. Results of this project indicate that the viability of integrating winter camelina into organic pig production depends on production costs, crop yield, and market development for organic pigs and camelina products.

Accomplishment of Objective 1) Determine the optimal amount of camelina press-cake as a feed ingredient for pigs: A feeding trial using 192 pigs to test four levels (0% as control, 5%, 10%, and 15%) of camelina press-cake (CPC) to replace corn and soybean meal (SBM) was conducted. Results suggest that replacing corn and SBM with CPC had minimal impact on pork quality (Zhu et al., 2021). Feed intake, weight gain, market weight, carcass weight, and dressing percentage of pigs decreased as dietary CPC inclusion rate increased, but feed efficiency was not affected (Hilbrands et al., 2021). Supplementing up to 10% CPC did not elicit negative effects on carcass traits or pork quality. Accomplishment of Objective 2) Grow organic camelina in a double-crop system with soybeans and evaluate its impact on yield, cost, and return: Winter camelina was grown on 8 ha organic-certified land, as a single crop or relay-planting with soybeans to increase the total yield per hectare. Camelina seed yield was 1,394 kg ha⁻¹ in the monocrop field. The total oil seed (camelina plus soybean) yield in the relay field was 1,894 kg ha⁻¹, accounting for 135% of the camelina yield in the monocrop field. The total of camelina production costs and reduced revenues compared to soybean production was \$967 ha⁻¹ for the monocropping scenario and \$883 ha⁻¹ for the relay-planting scenario. The camelina seed would need to be sold at a minimum price of \$0.69 kg⁻¹ if monocropping, or \$1.29 kg⁻¹ if relay-planting to cover production costs and reduced revenues caused by the decreased soybean yield. Although the total yield of camelina and soybean in the relay-planting field was higher than camelina yield in the monocrop field, monocropping camelina is more economical than relay-planting with soybeans due to the difference in production costs.

Accomplishment of Objective 3) Determine effects of dietary camelina press-cake supplementation on growth performance and meat quality of pigs that are raised under near-organic conditions: A feeding trial using 400 pigs was conducted under near-organic conditions. Pigs in the control group were fed organic corn and SBM based diets, and pigs in the treatment group were fed diets supplemented with 10% CPC to replace corn and SBM in the control diets for 16 weeks until they reached market weight (120 kg). Supplementation of CPC in pig diets reduced average daily feed intake (ADFI) and average daily gain (ADG), market weight, hot carcass weight, and dressing percentage of pigs, maybe due to glucosinolates in CPC (2.1 µmol/g of feed). Pigs fed treatment diets were 6.5 kg lighter than pigs fed control diets at market. Theoretically, pigs fed treatment diets would require an additional 6 to 7 days (based on ADG of 1.01 kg) to reach the final body weight of pigs fed control diets. Feed efficiency was not affected by dietary CPC inclusion. Dietary CPC supplementation did not affect pork quality (pH at 45 minutes and 24 hours after harvest, water holding capacity for juiciness, shear force value for tenderness, marbling scores and color scores for visual appearance), backfat thickness (at the first, 10th, and last ribs), belly firmness (measured by belly hang angle) or belly thickness. Supplementation of CPC in diets increased liver weight in pigs, indicating that glucosinolates in CPC increased metabolic burden on the liver of pigs. These results indicate that supplementing 10% CPC to replace corn and SBM in diets fed to pigs under near organic conditions did not affect feed efficiency or pork quality, but required an additional week for the pigs to reach the desired market weight.

Accomplishment of Objective 4) Economic analysis and life cycle assessment of two organic swine-cropping systems with and without camelina integration: Based on data collected for Objectives 2 and 3, and available data from CFFM (2021), the economic feasibility of integrating camelina into organic pig production was evaluated. The maximum purchase price of CPC that an organic pig producer would be willing to pay to cover the production costs is \$0.20 kg⁻¹. To be economically feasible, the minimum camelina oil sale price is \$7.59 kg⁻¹ if relay-planting or \$3.59 kg⁻¹ if monocropping. Collectively, results of the economic analysis suggest that the viability of integrating camelina into organic swine production would depend on market development for organic pigs and camelina oil.

Environmental impacts of integrating camelina into organic pig production were modelled using three standard metrics (greenhouse gas emissions (GHG), fossil energy use, and agricultural land use). Four scenarios (single vs. relay-planting with soybeans with actual vs. expected yield) of camelina production were examined. The use of camelina generated in this study by relay-cropping was compared to camelina produced in a single crop system. Two camelina relay systems (data from this study's actual vs. expected) were compared with the existing soybean system. The organic crop-pig production system was broken down into three areas: camelina cropping, processing of camelina grain into oil and CPC, and feeding CPC to pigs. Results indicate that for camelina in the four camelina cropping scenarios, GHG production was up to 380% higher and fossil energy use was up to 350% higher than in the soybean system, which was caused by energy use for camelina grain drying and fertilizer application. Likewise, winter organic camelina, produced either as a single crop or as a crop relayed with soybeans did not provide land use benefits when compared with soybean production in the region because camelina yields are lower than soybean yields. Fossil energy use for processing camelina was 1.06 MJ kg⁻¹ CPC, while GHG production was 0.0782 kg CO₂ eq. kg⁻¹ CPC. This compares to 0.587 MJ and 0.044 kg CO₂ eq. per kg⁻¹ SBM. Additionally, fossil energy use was higher for pigs fed diets supplemented with CPC (3.50 MJ kg⁻¹ live weight pork (LW)) compared to that for pigs fed corn and SBM in the control group (3.03 MJ kg⁻¹ LW). The same pattern was seen in GHG emissions, where pigs fed diets supplemented with CPC had GHG

emissions of 1.43 kg CO₂ eq. kg⁻¹ LW, compared to 1.31 kg CO₂ eq. kg⁻¹ LW for pigs in the control group. The exploratory life cycle assessment conducted for this project indicates that the use of organic CPC produced in relay-planting is not beneficial for reducing the selected environmental impacts (GHG, fossil energy, or land use) in organic swine production. With lower yields than soybeans, the environmental impacts of camelina produced in both cropping system (mono- and relay-cropping) were higher than soybeans. These increased environmental impacts followed the camelina grain into processing and use of camelina products in the downstream systems, such as organic pig production. **Publications** - Type: Journal Articles Status: Published Year Published: 2021 Citation: Zhu, Y., R. Cox, L. J. Johnston, C. Reese, F. Forcella, R. W. Gusch, and Y. Z. Li. 2021. Effects of increasing inclusion of camelina press-cake in diets fed to growing-finishing pigs on pork quality. *Appl. Anim. Sci.* 37:357-366. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Hilbrands, A. M., L. J. Johnston, R. B. Cox, W. F. Lazarus, F. Forcella, R. Gesch, and Y. Z. Li. Camelina meal as an alternative ingredient in growing-finishing pig diets - Type: Journal Articles Status: Awaiting Publication Year Published: 2021 Citation: Hilbrands, A. M., L. J. Johnston, R. B. Cox, W. F. Lazarus, F. Forcella, and R. Gesch, and Y. Z. Li. Utilizing camelina meal as an alternative feed ingredient in finisher pig diets. - Type: Journal Articles Status: Submitted Year Published: 2021 Citation: Y. Z. Li, W. F. Lazarus, C. Reese, A. M. Hilbrands, R. B. Cox, F. Forcella, R. W. Gesch, and L. J. Johnston. Integrating camelina into organic pig production Impact on growth performance of pigs, costs, and returns - Type: Websites Status: Published Year Published: 2021 Citation: Yuzhi Li. 2021. Feeding camelina to organic pigs. *WCROC Newsletter*. May 2021. <https://wcroc.cfans.umn.edu/research/swine/camelina-meal-organic-pigs> - Type: Other Status: Other Year Published: 2019 Citation: Lazarus, W. F. 2019. Camelina meal breakeven value calculations based on feeding trial results at the 10% and 5% replacement levels. An article shared with a state representative on the Winter Camelina Field Day. Waseca, MN. June 14, 2019. - Type: Other Status: Other Year Published: 2018 Citation: Li, Y. Z. 2018 (invited). Organic swine production in the United States. Presented at MN Organic Conference, St Cloud, MN. Jan 11-12, 2018. - Type: Other Status: Other Year Published: 2018 Citation: Li, Y. Z. 2018. Project overview. Presented at the Winter Camelina Field Day, organized by Agricultural Utilization Research Institute and University of Minnesota. Waseca, MN. June 27, 2018. - Type: Other Status: Other Year Published: 2021 Citation: Li, Y. Z. 2021. Reducing feed cost in organic pig production - Research update on camelina project. Presented to West Central Research and Outreach Center Advisory Committee on Feb. 23, 2021. - Type: Other Status: Other Year Published: 2021 Citation: Li, Y. Z. 2021. Reducing piglet mortality in a bedded, group farrowing systems. Presented at the Freedom in farrowing and lactation virtual workshop, Copenhagen, Denmark. Aug. 12-13, 2021. - Type: Journal Articles Status: Other Year Published: 2022 Citation: Tallaksen, J. Life cycle assessment of integrating camelina into organic swine production. In preparation. - Type: Conference Papers and Presentations Status: Published Year Published: 2018 Citation: Li, Y. Z. 2018 (invited). Behavior, welfare, and organic swine production Swine Research Update. Presented at 2018 Chinas Symposium on Livestock and Poultry Environment and Precision Animal Husbandry. Harbin, China. Sept. 3-5, 2018. - Type: Other Status: Other Year Published: 2018 Citation: Li, Y. Z. 2018. Behavior, welfare, and organic swine production Swine Research Update. Presented to Regional Extension Officers of the University of Minnesota. Morris, MN. Sept. 20, 2018. - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Li, Y. Z. 2019 (Invited). Reducing piglet mortality in loose farrowing systems. Presented at the Midwest Organic Pork Conference, Waterloo, IA. Mar. 8, 2019.

PROGRESS

2019/09 TO 2020/08 Target Audience: The target audience for this project is existing and potential organic farmers, their stakeholders, researchers, and agricultural professional. Preliminary results and progress of the project have been communicated with the audience through publications and field days. Changes/Problems: The project has been approved for one-year extension without additional cost. The new expiration date of the grant is set at August 31, 2021. The extended period will allow us to collect all data as proposed and complete the project successfully. In the animal trial for Objective 3, 80 pigs per group was proposed. However, sows did not perform well and had higher pre-weaning mortality under near-organic conditions than expected. The first group of sows (n=16) only weaned 123 pigs. Among them, 100 healthy pigs were selected for the first replicate of the animal trial, with 50 pigs being allocated to each treatment group. To keep the group size consistent across all replicates, 50 pigs per group was used. While the group size was reduced, all data collection and the number of pigs used for meat quality tests remained the same as proposed. Thus, the change in the group size will not affect the quality of the data or conclusions of the animal trial. Due to interruptions of COVID-19 pandemic, a planned presentation at the national ASAS conference was canceled, and consequently, an abstract was not published during this reporting period. The abstract will be submitted to a conference next year. Field days were changed to virtual. What opportunities for training and professional development has the project provided? The project has provided opportunities for a graduate student and a visiting scholar to be trained in organic pig research, and for the PDs to collaborate with agronomists, soil scientists, applied economists, and environmental scientists to

tackle tough issues in organic pig production. The project also provided opportunities for the PDs and investigators of this project to attend organic conferences and to interact with organic farmers. All these opportunities directly benefit the professional development of the PDs and the investigators, and indirectly enhance training graduate students, undergraduate students, and organic farmers. How have the results been disseminated to communities of interest? Available results have been disseminated to organic farmers, pig producers, and communities of agriculture through publications and presentations. Articles related to this project were published in social media, newsletters, and newspapers. The project was presented on virtual field days to researchers, farmers, and stakeholders. Virtual field days were organized by the University of Minnesota and USDA-ARS Morris, MN. Winter Camelina: Environmental benefits, breeding, and agronomics. May 26th, 2020. Winter Camelina: Food science and end use application. June 2nd, 2020. Winter Camelina: Supply chain and market development. June 9th, 2020. What do you plan to do during the next reporting period to accomplish the goals? Objective 1: Publish the results in peer-reviewed journals Objective 2: Conduct an economic analysis of the organic winter camelina system compared to a traditional organic system. Objective 3: Complete the animal trial and lab work for meat quality tests. Conduct statistical analyses of the data, and draft a manuscript for publication in a peer-reviewed journal. Objective 4: Complete data collection of input and output for two organic swine-cropping systems with and without camelina integration. Conduct economic and life cycle analysis for each system. Draft a manuscript for publication. All activities mentioned above will be communicated with organic farmers, and other interested audience through seminars, conferences, newsletters, social media, and publications. Four manuscripts will be prepared for publication. Progress of the project will be updated in newsletters of the University of Minnesota's West Central Research and Outreach Center, and the University of Minnesota Extension website.

IMPACT

2019/09 TO 2020/08 What was accomplished under these goals? This project is the first to investigate integrating winter cover crops - camelina into organic pig production systems. The overarching goal is to evaluate whether growing winter camelina as a feed ingredient could reduce feed cost and increase financial return for organic pig farmers. Objective 1 (Evaluate the optimal supplemental amount of camelina meal as an alternative feed ingredient for pigs) was achieved by using 192 pigs to test four levels (0% as control, 5%, 10%, and 15%) of camelina meal to replace corn and soybean meal. Results suggest that replacing corn and soybean meal with camelina meal at 10% or lower level will not have a significant impact on the growth and meat quality of organic pigs. All data were subjected to statistical analysis and are ready for publication. Currently, two manuscripts (one for growth performance and another for meat quality) are prepared for publication in peer-reviewed journals. The field work for Objective 2 (Grow organic camelina in a double-crop system with soybean and evaluate its impact on total yield and cost return) was completed during this report period. Winter camelina was seeded on 20 acres of organic-certified land at the University of Minnesota's West Central Research and Outreach Center (WCROC). Among the 20 acres, 11 acres were used for a single crop of camelina and the other 9 acres were used for relay cropping with soybeans. Row spacing was 6 inches for the camelina in the monocrop field, with a seeding rate of 7 lb per acre. In the relay cropping field, camelina was seeded the same way except that a row was skipped every 30 inches, with a seeding rate of 5 lb per acre. Soybean was seeded at 180,000 seeds per acre in the 30-inch skip rows in the relay cropping field. Camelina was harvested 40 days after soybean was seeded. At harvest, soybeans in the relay cropping field were in the 4-leaf stage. During harvest, camelina was cut about 8 inches above the ground in the monocrop field and about 12 inches above the ground in the relay cropping field to avoid cutting the soybeans. The difference in cutting height between the monocrop and relay cropping field may be associated with low yield of camelina in the relay crop field because camelina seed pods between 8 and 12 inches were not harvested. Camelina yield was 1,404 lb per acre in the monocrop field and 689 lb per acre in the relay crop field, with 25% moisture content. The cool wet spring/summer resulted in a later harvest date and higher moisture content for camelina. In general, yield of organic camelina is comparable to yield of conventional camelina which is about 800 to 1200 lb per acre. Yield of soybean in the relay crop field was 18 bu per acre, which was about 1/3 to half the yield of organic soybean in monocrop systems. Camelina seeds were cold-pressed at an organic oilseed processing plant. Camelina seed and meal were analyzed for amino acid profile, crude protein, fatty acid profile, neutral detergent fiber (NDF), and energy content. Camelina meal generated has been used in the animal trial for Objective 3. To achieve Objective 3 (Effect of camelina meal supplementation on growing performance and meat quality of pigs raised under near-organic conditions), 120 pregnant sows in four contemporary groups were fed organic feed and managed near-organically from the 3rd trimester. Each group consisted of 30 sows in two gestation pens. Among them, 16 sows farrowed within a week in two bedded rooms (8 sows/room) under near-organic conditions. In total, 64 sows generated 400 pigs for the study. The pigs were used in four replicates to achieve Objective 3. Within each replicate, 100 pigs balanced for sex were housed in two pens in a growing-finishing hoop barn. One pen housed a control group of pigs fed corn-soybean basal diets, and another pen housed a treatment group of pigs fed basal diets supplemented with 10% of camelina meal. Pigs

received control or treatment diet after a two-week adaptation period to the hoop barn and remained on their dietary treatments for 16 weeks until they reached market weight of 110-120 kg. Feed intake was recorded on a group basis. Feed usage by sows were recorded from the 3rd trimester (from 80 days after breeding) until weaning. Feed intake of nursery pigs in each group-farrowing room was recorded, and average daily feed intake for pigs in each room was estimated. For growing-finishing pigs, feed addition was recorded for each pen. Leftover feed in each feeder was weighed every four weeks, and again at the end of the study when all pigs were marketed. Average feed intake was estimated using the total amount of feed addition divided by the number of pigs and the number of days on feed. All pigs were weighed individually at weaning before being transferred to the growing-finishing barn, every four weeks thereafter, and when pigs reached market weights. Average daily gain and feed efficiency were calculated for the nursery and growing-finishing period, respectively. Among the four replicates proposed for the animal trial, two replicates have been completed, and the other two replicates are in the process of data collection. The last objective (Objective 4: Economic analysis and life cycle assessment of two organic swine-cropping systems with and without camelina integration) has been addressed throughout the entire process of the project. Since the animal trial is still in progress, final economic analysis and life cycle assessment is not available at this point. ****PUBLICATIONS (not previously reported):**** 2019/09 TO 2020/08 1. Type: Websites Status: Published Year Published: 2019 Citation: Diane DeWitte. 2019. U of M currently conducting organic swine research. Available at: <https://www.thelandonline.com/news/u-of-m-currently-conducting-organic-swine-research/article/888dc06c-0c97-11ea-b2c4-4fb4bdbca935.html> 2. Type: Websites Status: Published Year Published: 2019 Citation: Johnston, L., Y. Li, A. Hilbrands, R. Cox, W. Lazarus, W. Martin, F. Forcella, R. Gesch. 2019. Is feed camelina meal to pigs a good option? Farm Journal's Pork. Available at: <https://www.porkbusiness.com/article/feeding-camelina-meal-pigs-good-option> 3. Type: Websites Status: Published Year Published: 2019 Citation: Johnston, L., Y. Li, A. Hilbrands, R. Cox, W. Lazarus, W. Martin, F. Forcella, R. Gesch. 2019. Camelina use may support pig growth, soil health. Feed Navigator. com. Available at: <https://www.feednavigator.com/Article/2019/04/18/Camelina-use-may-support-pig-growth-soil-health> 4. Type: Websites Status: Published Year Published: 2020 Citation: Reese, C., Y. Li, R. Gesch, and F. Forcella. Growing winter Camelina organically. 2020. WCROC. Newsletter. April. 2020. <https://wcroc.cfans.umn.edu/wcroc-news/organic-winter-camelina> 5. Type: Websites Status: Published Year Published: 2020 Citation: Li, Y. Z. 2020. Can camelina meal be used as a feed ingredient to reduce parasites in organic pig production? WCROC. Newsletter. June 2020. Available at: <https://wcroc.cfans.umn.edu/wcroc-news/camelina-feed-ingredient> 6. Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2020 Citation: Hilbrands, A. M., L. J. Johnston, R. B. Cox, W. F. Lazarus, F. Forcella, R. Gesch, and Y. Z. Li. Camelina meal as an alternative ingredient in growing-finishing pig diets (Abstract, waiting for publication) 7. Type: Journal Articles Status: Other Year Published: 2020 Citation: Hilbrands, A. M., L. J. Johnston, R. B. Cox, W. F. Lazarus, F. Forcella, and R. Gesch, and Y. Z. Li. Utilizing camelina meal as an alternative feed ingredient in finisher pig diets. (in preparation) 8. Type: Journal Articles Status: Other Year Published: 2020 Citation: Y. Zhu, R. Cox, L. J. Johnston, C. Reese, R. Gesch, and Y. Z. Li. Effect of dietary supplementation of camelina meal to growing-finishing pigs on pork quality (in preparation)

[↑ Return to Index](#)

Facilitating Improved Environmental and Soil Quality Through Increased Biodiversity and Crop/livestock Integration on Organic Farms

Accession No.	1013533
Project No.	MO-C00058319
Agency	NIFA MO.\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2017-51106-27007
Proposal No.	2017-03371
Start Date	01 SEP 2017
Term Date	31 AUG 2020
Grant Amount	\$499,927
Grant Year	2017
Investigator(s)	Clark, K.; Kremer, RO, J.; Hendrickson, MA, .; Massey, RA, .; Pathan, SA, M.; Murakami, CH, .

NON-TECHNICAL SUMMARY

Agricultural systems that restore biodiversity improve sustainability and lower dependence on external inputs, which is vital in organic production. One way to increase the ecosystem services provided by species diversity in an organic system is to expand the role of cover crops. The focus of this project is on research, education and extension and the main goal is to investigate the effects of integration of cover crops and livestock grazing on soil quality and crop yield. Research and outreach will be conducted on organic certified land at Missouri's land grant universities and on land provided by on-farm cooperators. Results will be utilized in the development of educational programs on organic crops, livestock and soil health through university curriculum development, courses on organic principles and practice, open-source learning modules, and producer outreach. College students in the organic classes will help design and implement the research and outreach. Calculation of economic benefits will aid in grower decision-making and assist in long-term investment into improved soil health and on-farm biodiversity. These goals address priority one of the ORG Program and will increase awareness within the organic community of the cumulative effects of increased biodiversity on ecosystem services and the long-term sustainability of organic farms. The educational programming will improve understanding of organic principles by students who are both today's consumers and tomorrow's farmers and future drivers of agricultural policies and practices. Intermediate and long-term outcomes include producer adoption of practices increasing on-farm biodiversity, leading to greater economic and environmental stability in organic production.

OBJECTIVES

The goal of this research project is to investigate the effects of increased biodiversity in an organic system on carbon storage, soil quality, and reduced need for external inputs of nitrogen. This will be done using multi-functional cover crops in an integrated crop/livestock system. In addition to providing research in organic cropping systems, it is also important to engage in outreach and education. Many outreach programs focus on land manager education, but we believe it is important to address attitudes and perceptions of organic agriculture at an even earlier stage. Therefore, an additional goal of this project is to develop, provide and present educational curriculum on organic cropping practices for college courses. Producer education will also be a vital part of our extension component. The focus of this project is on research, education and extension. These goals address

priority one of the Organic Transition Grants Program, which entails documenting and understanding the effects of organic practices on ecosystem services, greenhouse gas mitigation and biodiversity. The specific objectives of the proposal are: Quantify yield and soil and environmental quality indicators in an integrated organic cropping system that utilizes livestock grazing of cover crops. Develop and implement educational programs on organic crops, livestock and soil health through: University curriculum on organic animal and crop production and creation of an Organic Principles and Practices course and an internship course in Organic Research and Production at the University of Missouri. Open-source learning modules. Integration of organic research results into Lincoln University curriculum. Provide extension and outreach to organic and transitioning producers with a focus on cover crops and crop/livestock integration. Calculate economic benefits of crop/livestock integration in an organic system. As the two land grant colleges in Missouri, Lincoln University (LU) and the University of Missouri (MU) both have research programs focused on solving real-world problems of the state's agricultural practitioners, including programs dedicated to organic research. In an effort to best utilize the strengths of both programs and to provide the broadest and most effective outreach, LU and MU will collaborate on research, extension and education objectives on this project.

APPROACH

This research will be conducted at several sites in central Missouri including the LU Busby Organic Research Farm in Jefferson City, MO and two on-farm trials. Methods for objective one: Quantify soil quality indicators and yield in an organic cropping system that utilizes livestock grazing of cover crops. A cover crop mix of cereal rye and spring oats will be sowed in August each year and grazed at one of four grazing times (none, fall, spring, fall+spring). The seeding rate for oats and for rye that will be grazed will each be 134 kg ha⁻¹ (120 lbs/acre/species). Generally, high seeding rates are used for cover crops being grazed by animals. To help elucidate the effect of such a high cover crop seeding rate on both soil quality and seed germination and yield of the subsequent cash crop, a lower density of cover crop will also be examined (half of the high rate). The cover crops will be terminated in the spring with disking and soil incorporation before crop planting. An experimental control will have no cover crops, thus no subsequent grazing. Electric fencing will be erected so that grazed plots are separated from non-grazed plots. Animals will be grazed using intensive rotational grazing and left on each grazed plot until all vegetation has been grazed to a height of approximately 3 inches, then animals will be rotated. The summer cash crops will be a corn-soybean rotation with multiple entry points in the same field for the three year study and will be planted in 76 cm (30 inch) rows. Individual plots will be in a randomized complete block design and will be 12 meters (40 ft) wide x 12 meters long. There will be 12 treatments with 4 replications for a total of 48 plots per location. Weed control in the corn and soybeans will be accomplished through use of between-row cultivation. Corn and soybean will have the middle two rows harvested and yield will be calculated using harvested grain weight adjusted for standard moisture. Soil Data Collection Carbon Sequestration will be evaluated as total soil organic carbon using a LECO® Tru-Spec C/N Analyzer. Active Carbon: Will be determined using the potassium permanganate test as described by Weil et al. (2003) and modified by Culman et al. (2012). Mineralizable N: For 7-day anaerobic PMN, samples are extracted in a 1M KCl solution and NH₄⁺-N is quantified using the colorimetric microplate method of Rhine et al. (1998). PMN is calculated by subtracting the initial NH₄⁺-N value from the post-incubation NH₄⁺-N value. Microbial activity: Activity of β-glucosidase is determined with p-Nitrophenyl-β-D-glucoside (PNG) substrate solution and read in a spectrophotometer at 410 nm. Microbial community analysis: Phospholipid fatty acid analysis will be determined using the method of Buyer and Sasser. Due to the high cost of this testing, it will only be conducted at one location. Cover crop biomass: Total above-ground biomass produced by cover crops will be calculated by collecting samples from within a randomly placed 1 m² frame prior to cover crop termination in spring. Soil Nutrient Testing: Samples will be analyzed for macronutrient levels, SOM, pH and CEC at the University of Missouri Soil and Plant Testing. Aggregate stability will be determined by the wet sieving method (Nimmo et al., 2002). Compaction: Bulk density will be determined at the top 8 cm by gravimetric methods (Burt, 1992). Methods for objective two: Develop University curriculum on organic animal and crop production and creation of an Organic Principles and Practices course and Internship in Organic Research and Production at the University of Missouri. The course will be designed using a Communities of Practice approach that will expose students to the authentic tools, issues, and dilemmas of organic farm practitioners. The course will incorporate regional farmer concerns into the curriculum using research-based pedagogical approaches e.g. problem based learning and socioscientific issues-based learning. The general framework of the course will include the following: Field trips to regional organic producers, organic research farms, and producers considering transitioning to organic. Decision-making teaching units focused on managing soil health, animal health, plant health, and marketing, but associated with regional farm issues/dilemmas. Organic Farm Plan Assignment Develop and help implement and analyze the organic research outlined in this proposal. Produce outreach and extension publications on organic research results. A separate course will also be offered that will enable internships either with MU or LU organic researchers or the producers involved in this research study. Students will assist in planning and conducting the crop/livestock integration

research on collaborating farms? Open-source learning modules. Appropriate lectures developed for the organic course will be made into online classes and made available as open-source learning using the Moodle learning management system. This software platform will allow MU and LU to offer non-credit learning opportunities to the general public. In addition to classroom lectures, case studies and multi-media presentations will become available on Moodle. The availability of open-source learning modules will be advertised using existing organic groups such as MOSES, eOrganic and MOA. Methods for objective three: Provide extension and outreach to organic and transitioning producers with a focus on cover crops and crop/livestock integration. Research information from LU and MU will be presented at annual Organic Field Days to be held at farms of research collaborators. Collaborators will also serve as speakers and sources of information for the public. Students in the Organic Principles and Practices class and the Organic Research Internship will help plan and implement field days. Virtual Field Days will be employed on this project, which are multi-media presentations following the annual life of a research project. This allows us to reach a larger audience than traditional in-person field days. Virtual field days will be produced by students in the Organic Principles and Practices class and the Organic Research Internship and will be accessible through YouTube. Research results will also be posted on the MU Organic Agriculture webpage and Facebook page. These pages will be administered by students in the Organic educational program. Much of the information produced and collected during this research project will be made into extension publications and made available to the public via the MU and LU Extension publications offices. Extension publications will be produced on cover crops in organic systems and integrating crops and livestock in an organic system. Presentations on new organic research results and the educational tools we develop will be made by the MU organic research staff at the Mid-America Organic Association (MOA) conference each year at the Midwest Organic and Sustainable Education Service (MOSES) in year three of the grant. Methods for objective four: Calculate economic costs and benefits of increased diversity in an organic crop and livestock system. A cost-benefit and sensitivity analysis will be done on each cropping system and its accompanying cover crop/livestock grazing activity. Cost of production will be estimated using actual field practices and inputs. Commodity crop and cover crop/livestock returns will be calculated using experimental yields. All benefits for which a market exists will be included at market value as reported in market databases. Benefits for which a market does not exist (e.g. increased water holding capacity, increased organic matter) will be valued using other published economic research results. A spreadsheet model that takes into account fixed and variable costs and the multi-year time horizon of cover crop/grazing decisions will be developed. ****Progress**** 09/01/17 to 08/31/21 ****Outputs**** Target Audience: Our audience included undergraduate students taking the Organic Production class. It also included Missouri organic growers and those using organic practices without certification. This audience was invited to on-farm field days and was given one-on-one assistance as requested. NRCS and Extension staff also worked with the MU organic program to provide services to farmers across the state. Our extension efforts reached approximately 140 organic and transitioning farmers at summer field days and another 500 growers, agricultural professionals and government staff at the Mid-America Organic conference. We reached approximately 120 researchers and students from around the nation at the American Society of Agronomy Conferences and an additional 60 researchers, farmers, and governmental staff from US programs at the SARE conference. We also reached 2200 high school students in Missouri. Changes/Problems: Lincoln University was a collaborator on this grant. We intended to utilize the Lincoln University Busby Organic Research Center as a site for research trials. However, in 2017 LU experienced deep budget cuts and laid off most of their farm staff. Because of this, the farm no longer had the staff capacity to conduct this research. Therefore, we utilized a hog farmer in Frankenstein, MO as our third research site. LU researcher S. Pathan continued to collaborate with the University of Missouri researchers, although the LU farm was no longer part of the project. In year one of the project he was moved to a 100% research appointment, thus no longer taught crop science. Severe drought was experienced in the fall of 2017 and spring-summer of 2018, which led to poor cover crop and crop emergence at the research sites. Equipment problems in the summer of 2018 (project tractor lost its PTO) also led to delayed organic weed control in soybeans, resulting in no crop yields for soybean at the three sites. Corn yield in 2018 was collected only at the Cope site. The Linnenbringer and Kremer sites had no ears on the corn plants due to drought. Weed pressure caused crop failure at two research sites in 2019. One field was replanted but did not yield a viable grain crop for harvest. Late maturity of cash crops delayed cover crop planting in 2018-2020, leading to slow fall growth and no capacity for fall grazing of animals. Dry weather and low germination of cash crop in spring 2020 led to planting of sorghum sudangrass at two locations. The third location was planted with corn and soybean but had high summer weed growth in plots. The Linnenbringer farm uses no tillage and our attempts to provide organic no-till weed control proved difficult. The cover crop residue provided some weed control in plots with cover crop. Non-cover crop plots had pre-plant weed control using a broadcast flamer, and seasonal weed control using a between-row mower. However, weed growth in most plots was still high and the grasses were difficult to control using the between-row mower. The presence of cover crop residue raised the risk of a wildfire if the flamer had been used for weed control in the corn plots. At the Kremer Farm, the residual weedbank from previous years of low weed control was a strong force. The research field was inundated with cocklebur, which was difficult to control with a cultivator due to a side slope in the field that pulled equipment into the crop row. As

a result of these issues, cash crop yields were only viable at the Cope Farm. Cope allowed tillage in the second and third years of crop production. Poor weather conditions led to limited cover crop growth after grazing, thus only one grazing cycle was possible in the spring most years. Farmers also had difficulty moving animals into the plots and the cattle knocked down the electric fence in 2018. Although the Cope Farm had adequate regrowth for a second planting in 2019, the farmer did not have the time or resources to move the animals back to the area of the farm where the research plots were located. The combination of cover crop grazing, moving animals, and organic cash crop production made this a challenging project. Conventional weed control would have made the cash crop production far easier. What opportunities for training and professional development has the project provided? Emily Miller earned her MS degree in Rural Sociology through this grant funding. Ms. Miller collaborated on development of organic education at the University of Missouri and conducted research on the difficulties in organic certification experienced by farmers in the Mid South. Kerry Clark and Md. S. Pathan attended the November, 2018 American Society of Agronomy Conference in Baltimore, MD. Kimberly Griffin attended the 2019 Soil Science Society of America Conference in San Diego, CA. Emily Miller attended the 2019 Rural Sociology Conference in Richmond, VA. Kerry Clark and Md. Pathan attended the 2019 and 2020 (virtual) American Society of Agronomy Conferences and Mary Hendrickson and Emily Miller attended the 2020 (virtual) Rural Sociology Society Conference. Emily Miller also participated in the Midwest Organic and Sustainable Education Service and the Southern Sustainable Agriculture Working Group 2020 Annual Conferences. How have the results been disseminated to communities of interest? On July 29, 2018 we held a field day on Organic Transitioning in Poplar Bluff, MO on an organic farm owned by Don DeLozier and co-hosted by Midwest BioAG and Pipeline Foods that was attended by 20 area farmers. This part of Missouri (Mississippi River delta) is traditionally low in organic production but due to its high productivity, buyers are interested in recruiting organic farmers from the area. A major topic of discussion ended up being the difficulty of organic and non-GMO soybean production in the area due to the large scale of dicamba damage experienced by all farmers not growing dicamba resistant soybeans. A second field day was held August 29, 2018 in Arrow Rock, MO on an organic farm owned by Derek Davis and co-hosted by River Valley Ag Exchange, an organic elevator and farm supply company located in Marshal, MO. Attended by 120 farmers, this field day was focused on organic weed control and Gary McDonald was the primary speaker. Gary detailed soil health and cultivation methods for a full day. We also had equipment demonstrations, including a Weed-Zapper, which kills weeds with electrical current, and the University of Missouri between-row mower. On January 24-26, 2018, we had a booth at the Mid-America Organic Conference in Kansas City, MO and presented information on organic production in Missouri. The event was attended by 600 midwest organic growers and other interested parties such as Extension and NRCS. On April 5, 2018, Kerry Clark presented our field research for the ORG project to 60 farmers and scientists at the SARE Our Farms, Our Future National Conference. This was done at the farm of research collaborator Harry Cope. On September 6, 2017 we presented 22 fifteen minute talks on organic production to 22 Missouri high school students. We continue to reach Missouri farmers through our research center website at <https://bradford.missouri.edu>. Kerry Clark spoke on our cover crop grazing research at three Byron Seed Field days for organic producers on January 7-10, 2019 in northern Missouri. These field days targeted Amish and Mennonite producers and had approximately 300 participants. On September 10, 2019, we co-sponsored the University of Missouri/River Valley Ag Exchange Organic Field Day in Nelson, MO. The event focused on cover crops and was attended by 170 organic growers, Extension and NRCS staff. Results were disseminated through the 2020 Mid-America Organic Association Conference and the University of Missouri/River Valley Ag Exchange field day in August 2020. This was attended by 100 producers and ag professionals. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? Environmental Quality Research Integrating crop and livestock agricultural production systems is an innovative solution to the global challenge of mitigating the negative effects of agriculture on the environment while intensifying production to meet food security needs. At the farm scale, integrated crop-livestock systems make more efficient use of on-farm resources, resulting in improved nutrient recycling, soil health, and profitability. In the Midwestern U.S.A., using cover crops as livestock forage during late fall, winter, and early spring following a summer row crop has been a viable integration method, but an understanding of best practices is critical to promote adoption regionally. Over a three-year period, we examined the effects of spring cover crop grazing on soil quality parameters on three Missouri farms under organic management using different livestock at each farm (sheep, cattle, and pigs). We used a randomized block design to evaluate three cover crop treatments (none, low seeding rate, high seeding rate) and two grazing variables (none, spring) on carbon sequestration, active carbon, soil nutrients, microbial community, soil moisture, and soil structure (aggregate stability and compaction). Using repeated measures models, we determined that time of sampling affected carbon sequestration and active carbon, though not in any singular direction, suggesting these parameters fluctuated greatly between sampling times. We used generalized linear mixed models to find that no other soil quality parameters were affected by the treatments tested. Our results suggest that spring grazing cover crops does not change soil health within three years, and that this strategy may be an effective crop-livestock integration tool for organic producers in Missouri. This study showed that there were no negative effects of cover

crop grazing on soil health parameters. Grazing cover crops could bolster profitability of farmland in Missouri by providing opportunity to raise dairy or meat and crops on the same land. However, grazing times were short, and two farms' plots were already in pasture prior to implementing the treatments, so the treatments may not have been enough to cause any changes. We were not able to test fall grazing in this study due to limited fall cover crop growth. Grazing the cover crops also negatively impacted the ability of the cover crops to suppress weeds as thick residue, which in turn affected summer crop production.

Educational Programs University curriculum on organic animal and crop production was created and delivered in the Organic Principles and Practices course for two semesters in 2018 and 2020. Six students participated in internships on cover crops for organic farms. Open Source Learning modules named "Organic Lessons from the Field" were created and posted here (https://www.youtube.com/channel/UCVXICnfZhAxd9-185x_1RAA/playlists). Two students from Lincoln University engaged in the Organic Internship and Lincoln University professor S. Pathan integrated organic production into his crop science class. Providing university curriculum and instruction on organic production enables system-wide support for organic agriculture as students assume future positions as teachers, researchers, policy makers, or in agribusiness. Extension and Outreach Our Extension Activities are detailed in the section on result dissemination. Throughout the project, we partnered with Missouri organic production organizations (MOA) and private sector organic support (River Valley Ag Exchange) to bring extension opportunities to Missouri producers.

Publications - Type: Journal Articles Status: Accepted Year Published: 2021 Citation: Miller, Emily M., Mary Hendrickson, Christopher Murakami, Kerry Clark. 2021. Blanket NOP Rules and Regional Realities: From the Field. Renewable Agriculture and Food Systems. Manuscript number: RAFS-D-20-00148 - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Emily Miller, 2019. USDA Certified Challenges: Key Perceptions of Organic Producers in the Mid-South US. Annual Meeting of the Rural Sociological Society. Richmond, VA. August 7, 2019

PROGRESS

2017/09 TO 2018/08 Target Audience: Our extension efforts reached approximately 140 organic and transitioning farmers at summer field days and another 500 growers, agricultural professionals and government staff at the Mid-America Organic conference. We reached approximately 120 researchers and students from around the nation at the 2017 American Society of Agronomy Conference and an additional 60 researchers, farmers, and governmental staff from US programs at the SARE conference. We also reached 2200 high school students in Missouri.

Changes/Problems: Lincoln University is a collaborator on this grant. We intended to utilize the Lincoln University Busby Organic Research Center as a site for research trials. However, in 2017 LU experienced deep budget cuts and laid off most of their farm staff. Because of this, the farm no longer had the staff capacity to conduct this research. Therefore, we are utilizing a hog farmer in Frankenstein, MO as our third research site. LU researcher S. Pathan continues to collaborate with the University of Missouri researchers, although the LU farm is no longer part of the project. Severe drought was experienced in the fall of 2017, and spring-summer of 2018, which led to poor cover crop and crop emergence at the research sites. Equipment problems in the summer of 2018 also led to poor organic weed control in soybeans, resulting in no crop yields for soybean at the three sites. Corn yield in 2018 will be collected only at the Cope site. The Linnenbringer and Kremer sites have no ears on the corn plants due to drought. What opportunities for training and professional development has the project provided? Kerry Clark attended the November, 2017 American Society of Agronomy Conference in Tampa, FL. How have the results been disseminated to communities of interest? Because we do not have any data to present yet on this first year of research (harvest has just begun), we focused on other topics in our extension events in 2018. On July 29, 2018 we held a field day on Organic Transitioning in Poplar Bluff, MO on an organic farm owned by Don DeLozier and co-hosted by Midwest BioAG and Pipeline Foods that was attended by 20 area farmers. This part of Missouri (Mississippi River delta) is traditionally low in organic production but due to its high productivity, buyers are interested in recruiting organic farmers from the area. A major topic of discussion ended up being the difficulty of organic and non-GMO soybean production in the area due to the large scale of dicamba damage experienced by all farmers not growing dicamba resistant soybeans. A second field day was held August 29, 2018 in Arrow Rock, MO on an organic farm owned by Derek Davis and co-hosted by River Valley Ag Exchange, an organic elevator and farm supply company located in Marshal, MO. Attended by 120 farmers, this field day was focused on organic weed control and Gary McDonald was the primary speaker. Gary detailed soil health and cultivation methods for a full day. We also had equipment demonstrations, including a Weed-Zapper, which kills weeds with electrical current, and the University of Missouri between-row mower. On January 24-26, 2018, we had a booth at the Mid-America Organic Conference in Kansas City, MO and presented information on organic production in Missouri. The event was attended by 600 midwest organic growers and other interested parties such as Extension and NRCS. On April 5, 2018, Kerry Clark presented our field research for the ORG project to 60 farmers and scientists at the SARE Our Farms, Our Future National Conference. This was done at the farm of research collaborator Harry Cope. On September 6, 2017 we presented 22 fifteen minute talks on organic production to 22 Missouri high school students. We continue to reach Missouri farmers through our

research center website at <https://bradford.missouri.edu> What do you plan to do during the next reporting period to accomplish the goals? During the next reporting period, we will collect and analyze crop yield and soil quality data from the 2018 growing season. We will continue to graze animals at the three research sites and follow research protocols to grow crops after grazing and monitor soil quality changes. We will conduct field days on organic practices, including grazing cover crops, in summer 2019. We are teaching the Organic Practices class in fall of 2018. We will have research internships for students in 2019 We will develop online educational material We will publish a website dedicated to organic production research at the University of Missouri

2019/09 TO 2020/08 Target Audience:Because the Organic Production class was taught in fall of 2020, our audience included undergraduate students. It also included Missouri organic growers and those using organic practices without certification. This audience was invited to a on-farm field day and was given one-on-one assistance as requested. NRCS and Extension staff also worked with the MU organic program to provide services to farmers across the state. Changes/Problems:Slow cover crop growth in fall inhibited and prevented fall grazing. Dry weather and low germination of cash crop in spring 2020 led to planting of sorghum sudangrass at two locations. The third location was planted with corn and soybean but had high summer weed growth in plots. What opportunities for training and professional development has the project provided?Kerry Clark and Md. Pathan attended the 2019 and 2020 (virtual) American Society of Agronomy Conferences and Mary Hendrickson and Emily Miller attended the 2020 (virtual) Rural Sociology Society Conference. Emily Miller also participated in theMidwest Organic and Sustainable Education Service the Southern Sustainable Agriculture Working Group 2020 Annual Conferences. How have the results been disseminated to communities of interest?Results have been disseminated through the 2020 Mid-America Organic Association Conference and the University of Missouri/River Valley Ag Exchange field day in August 2020. What do you plan to do during the next reporting period to accomplish the goals? Complete harvest of cash crops Complete lab analysis of soil Complete economic analysis Post online educational modules Post class curriculum online Complete and publish manuscripts

IMPACT

2017/09 TO 2018/08 What was accomplished under these goals? This project has not yet completed one full cropping cycle, so results are limited. The specific objectives of the proposal and items accomplished under each goal are listed below: Quantify yield and soil and environmental quality indicators in an integrated organic cropping system that utilizes livestock grazing of cover crops. In January 2018, a research specialist was hired to complete the field work on this project. Pre-graze soil samples were taken in Fall, 2017 at the three collaborating farms and samples were taken at the Cope Farm 7 days after fall graze but no samples were taken at the 14 day mark due to freezing conditions. The Linnenbringer Farm did not fall graze due to limited cover crop growth in the drought. Hogs at the Kremer Farm were not grazed in the fall due to their destructive grazing patterns. Seven and 14 day samples after grazing were collected at the three farms in the spring. Drought and poor weed control adversely affected cash crops at all three farms, with corn not putting on ears at two farms. Equipment failure coupled with environmental conditions led to poor organic weed control in soybean plots, so they were removed during the growing season to prevent further weed seed production. Develop and implement educational programs on organic crops, livestock and soil health through: In August 2018, a graduate student in rural sociology was given an assistantship to work on the curriculum part of the project. Chris Murakami, a co-PI on the project left MU to take a position at a college in PA. However, we re-hired him as a consultant, so he has continued to contribute to the project. In 2018, we created University of Missouri curriculum on organic animal and crop production and created an Organic Principles and Practices course and an internship course in Organic Research and Production at the University of Missouri. There are 16 students taking the class (started in August, 2018) and currently one student intern. We have begun to film some segments for open-source learning modules. Integration of organic research results into Lincoln University curriculum has not started because our collaborator has been reassigned from teaching to 100% research. We will be seeking new collaborations in the teaching faculty at LU in 2019. We have also created organic curriculum for the environmental science program at MU. Provide extension and outreach to organic and transitioning producers with a focus on cover crops and crop/livestock integration We held several field days in 2018, including one that focused on organic transitioning. The 2018 SARE National Conference had a field trip to the Cope Farm, where we presented this cover crop/grazing research to about 60 researchers, farmers and extension people from around the nation. Calculate economic benefits of crop/livestock integration in an organic system. Data has not yet been collected that would contribute to this objective. **PUBLICATIONS (not previously reported):** 2017/09 TO 2018/08 No publications reported this period. PROGRESS: 2018/09 TO 2019/08 Target Audience:Our extension efforts target organic and transitioning farmers at summer field days and growers, agricultural professionals and government staff at the

Mid-America Organic conference. We reach researchers and college students from around the nation at the American Society of Agronomy Conference. We target high school students at the annual University of Missouri Agricultural Education Field Day. Our education efforts are aimed at University students at the University of Missouri and Lincoln University as well as people looking for online content related to organic production.

Changes/Problems: Weed pressure caused crop failure at two research sites in 2019. One field was replanted but did not yield a viable grain crop for harvest. Late maturity of cash crops has delayed cover crop planting in 2018-2019, leading to slow fall growth and no capacity for fall grazing of animals. What opportunities for training and professional development has the project provided? Kerry Clark and Md. S. Pathan attended the November, 2018 American Society of Agronomy Conference in Baltimore, MD. Kimberly Griffin attended the 2019 Soil Science Society of America Conference in San Diego, CA. Emily Miller attended the 2019 Rural Sociology Conference in Richmond, VA. How have the results been disseminated to communities of interest? Kerry Clark spoke on our cover crop grazing research at three Byron Seed Field days for organic producers on January 7-10, 2019 in northern Missouri. These field days targeted Amish and Mennonite producers and had approximately 300 participants. On September 10, 2019, we co-sponsored the University of Missouri/River Valley Ag Exchange Organic Field Day in Nelson, MO. The event focused on cover crops and was attended by 170 organic growers, Extension and NRCS staff. What do you plan to do during the next reporting period to accomplish the goals? During the next reporting period, we will collect and analyze crop yield and soil quality data from the 2019 growing season. We will continue to graze animals at the three research sites and follow research protocols to grow crops after grazing and monitor soil quality changes. We will conduct field days on organic practices, including grazing cover crops, in summer 2020. We are developing online organic curriculum. We will have research internships for students in 2020.

IMPACT: 2018/09 TO 2019/08 What was accomplished under these goals? This project has completed two full cropping cycles. The specific objectives of the proposal and items accomplished under each goal are listed below: Quantify yield and soil and environmental quality indicators in an integrated organic cropping system that utilizes livestock grazing of cover crops. Seven and 14 day samples after grazing were collected at the three farms in the spring of 2019 and the soil has been analyzed in the lab for some parameters. Bulk density data was also collected pre and post graze. Cash crops are currently being harvested for the 2019 season. Develop and implement educational programs on organic crops, livestock and soil health through: The project graduate student, Emily Miller, has been conducting interviews to develop case studies for both online and educational modules and the MU and LU Organic courses. We have been filming segments for open-source learning modules. Provide extension and outreach to organic and transitioning producers with a focus on cover crops and crop/livestock integration. We collaborated with Byron Seeds in winter meetings in 2019 to reach an audience of Amish and Mennonite organic grazers. A field day on September 10, 2019 was conducted in collaboration with River Valley Ag Exchange and focused on the use of cover crops in organic production. Calculate economic benefits of crop/livestock integration in an organic system. Data has not yet been analyzed that would contribute to this objective.

PUBLICATIONS (not previously reported): 2018/09 TO 2019/08 Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Emily Miller, 2019. USDA Certified Challenges: Key Perceptions of Organic Producers in the Mid-South US. Annual Meeting of the Rural Sociological Society. Richmond, VA. August 7, 2019

2019/09 TO 2020/08 What was accomplished under these goals? This project has now completed three cropping cycles. We quantified yield and soil and environmental quality indicators for the second season of an integrated organic cropping system that utilizes livestock grazing of cover crops. During the past year, soil was evaluated in the lab for soil quality. Year three of the study was planted in fall of 2019, animals were grazed in 2019 and 2020, and that harvest is currently being conducted. Year three soil samples have been collected and will be analyzed in the lab over the winter of 2020-2021. The development and implementation of educational programs on organic crops, livestock and soil health through university curriculum on organic animal and crop production is ongoing and the Organic Principles and Practices course was taught for a second time in 2020. The course was modified for Covid-19 restrictions and was taught as an online, in-person hybrid. The curriculum will be posted online in spring 2021. The internship course in Organic Research and Production had three students in 2020 who worked on data collection. Five open-source learning modules were developed by the project MS student, with several of these incorporated into the university curriculum. These modules were developed from farmer interviews, then ask students to decide on case management, with a follow-up from an expert and response from the farmer on how they solved the problem presented. These modules are currently being edited and will be posted in late winter. Through collaboration with River Valley Ag Exchange in Marshall, MO, a field day was held for Missouri organic growers on August 25, 2020 and attended by 103 people. The subjects covered included cover cropping and soil health. The MU staff on this project also interfaced with Extension and NRCS on organic issues throughout the year and consulted one-on-one with approximately 20 producers.

PUBLICATIONS (not previously reported): 2019/09 TO 2020/08 Type: Journal Articles Status: Under Review Year Published: 2020 Citation: Miller et al. 2020. Blanket NOP Rules: A commentary. Journal of Renewable Agriculture and Food Systems. *under review

[↑ Return to Index](#)

Harnessing the Voracity of the Biocontrol *Tyta Luctuosa* to Improve Management of Field Bindweed During Transition to Organic and Beyond

Accession No.	1013517
Project No.	ORE00278
Agency	NIFA ORE\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2017-51106-27004
Proposal No.	2017-03399
Start Date	01 SEP 2017
Term Date	31 AUG 2020
Grant Amount	\$499,858
Grant Year	2017
Investigator(s)	Peachey, R. E.; Mallory-Smith, CA, .; Choi, MA, YE.; Moretti, MA, .

NON-TECHNICAL SUMMARY

The goal of this project is to develop and demonstrate ecologically based management plans for field bindweed so that producers transitioning to organic can successfully manage this weed. A second aim is to develop attractants for a biological control agent of field bindweed, and test and demonstrate how the attractants can be used to manipulate the biocontrol agent to enhance herbivory and improve the efficacy of ecologically based control plans. These goals are consistent with the goals of the ORG program because this project will improve the competitiveness of organic crop producers, particularly those that are adopting organic practices. The transition to organic production is fraught with challenges, and control of perennial weeds during the transition can be a major obstacle to success. If perennial weeds are left unchallenged during the transition period, the results can be catastrophic. Similarly, if the entire transition period is used to control perennial weeds, the results may be unsustainable because of lost income. The focus of this project is management of field bindweed because: 1) this weed is very common and difficult to control in organic systems, and 2) the biological control agent *Tyta luctuosa* is a voracious herbivore specific to field bindweed. Pheromone traps have allowed us to document where bindweed moths are distributed. We are now developing attractants that draw male and female moths directly to bindweed growing in crops to improve efficacy of this biological control agent, particularly when integrated with other control methods using flame, organic herbicides, or mulches.

OBJECTIVES

The goal of this project is to develop and demonstrate integrated weed management plans for field bindweed (*Convolvulus arvensis* L.) in organic systems so that organic producers and others transitioning to organic can reduce the impact of this pernicious weed. A secondary aim is to develop attractants for the field bindweed moth *Tyta luctuosa*, a biological control agent (BCA) of field bindweed. We propose to test and demonstrate how attractants can enhance herbivory and improve the efficacy of an ecologically based weed management plan. Additionally, this project will contribute to the development of cultural practices that may replace or reduce the need of some of the allowable alternatives and substances listed for organic production, including organic herbicides that are difficult to safely apply. These goals are consistent with the goals of the ORG program because this project will improve the competitiveness of organic crop producers, particularly those that are transitioning to organic practices. Objectives Engage producers in developing plans for control of field bindweed,

with a focus on successful release, management, and evaluation of *Tyta luctuosa* for potential to regulate field bindweed in perennial crops. Develop and refine attractants to improve potential of aggregating field bindweed moths onto field bindweed patches in fields that are transitioning to organic. Evaluate integration of cultural and biological control for field bindweed in organic perennial production systems. Report experience and discovery by cooperating producers and researchers as case studies and project summaries through e-Organic and traditional extension platforms and publications.

APPROACH

Objective 1. Engage producers in developing plans for control of field bindweed, with a focus on successful release, management, and evaluation of *Tyta luctuosa* for potential to regulate field bindweed in perennial crops. Team meetings with all project collaborators and participants will be held annually to summarize project gains, challenges that need to be addressed, and to plan outreach and extension activities. In year one of the project, the focus will be development of management plans with collaborators for field bindweed in organic perennial production systems, including berries, vineyards, nuts, and nursery systems. We will kick off the project in the fall of 2017 with a workshop where producers on the team will introduce their production systems, describe the challenges of managing bindweed in their systems, and outline the most effective strategies that they are using to minimize the impact of field bindweed on their crops. Cooperating researchers will summarize current state of the art equipment and practices that are in use worldwide to control field bindweed, including prevention, mechanical, organically approved chemical and thermal (including propane flame), and biological methods. Cooperators will be encouraged to develop bindweed management plans for specific sites on their farms. A portion of the initial workshop will focus on the biological control agents *Tyta luctuosa* and *Aceria malherbae*, to inform attendees that two agents do exist. Field visits will be scheduled in conjunction with the workshop so that stakeholders can learn how to release the BCA on their farms effectively, as well as monitor for the presence or absence, and evaluate symptoms of damage. An observational experiment will be initiated in Year 1 of the study to help cooperators assess the potential value of *T. luctuosa* in their cropping systems. Survival of *T. luctuosa* is not assumed in organic systems, given the use of Bt, spinosad, and other organically approved insecticides that are presumably detrimental to BCA survival. *T. luctuosa* larvae will be periodically released on bindweed at each site based on degree days, an estimation of larval development in Western OR (Green et al., 2015), and existing literature (Miller et al., 2000).

Objective 2. Develop and refine attractants to improve potential of aggregating field bindweed moths onto field bindweed patches in fields that are transitioning to organic.

BEHAVIORAL ASSAYS: Adult *Tyta luctuosa* will be collected from a known, existing field nursery in western Oregon, and maintained on a 10% honey and water solution. Fresh field bindweed bouquets as well as paper towels will be provided as oviposition substrates, and general rearing conditions will be as those described by Biever and Boldt (1971). Moths will be supplemented as needed from a professional insectary rearing facility with which we already have a working relationship. Larvae will be reared through pupation, when they will be examined to separate sex. Newly eclosed male and female adult moths will be placed in separate mesh cages and maintained as above. Male and female moths will be exposed to odorants using a modified olfactometer attached to a Plexiglass flight chamber. Investigators will offer to adult moths pure standards of previously identified compounds of interest applied to filter paper, as well as flowering or nonflowering bindweed, with or without prior exposure to *T. luctuosa* larvae to detect behavioral differences in detection and attraction. Positive attraction to each source will be quantified visually using a 0-5 rating system (erratic flight patterns, deliberate alighting, proboscis extension, staying on a source for ≥ 3 seconds, etc.) and recorded with a tape recorder for later transcription.

VOLATILE COLLECTIONS: Living bindweed plants will be placed in a glass collection jar and attached to a blower fan delivering air from a central lab source. The air will be directed through charcoal purification filters, over the experimental odorant (bindweed plant), and adsorbed onto Poropak-Q polymer traps or SPME fibers. Soil and pots within the jars will be covered with aluminum foil to reduce the possibility of confounding responses with soil volatiles. Compounds will be either eluted with dichloromethane (polymer traps) or directly injected (SPME) into a coupled gas-chromatography/mass-spectrometer (GC-MS) for analysis. Concurrent analysis will be performed via PTR-TOF and compared, because each analytical technique has different strengths.

FIELD: For the field component of Objective 2, *T. luctuosa* adults will be released into field cages on plot boundaries of the experimental area and allowed to acclimate. Caged releases are an accepted form of releasing BCAs, especially when they are highly mobile, such as *T. luctuosa* (Harney and Forno 1992). Attractants of interest that initiated a behavioral response in prior testing will be field-tested using a basic factorial study (lures with attractants vs. vs. lures without and timing of moth release) (Table 1). Lures will be placed inside odorant vials and placed on the soil surface, within randomly assigned marked patches of bindweed. Lures will not contact crop surfaces. Each location will have one of 3 'treatments' assigned to it (Table 1), with 3 replications, and the experiment will be conducted once in May and again in late August, to coincide with observed bi-voltinism of *T. luctuosa* in this region (Green et al. 2014).

Objective 3. Evaluate integration of cultural and biological control for field bindweed in organic perennial production systems. Weed control treatments evaluated will include steam, flaming, and organic herbicides. The

commercially available weed steamer from Weed Techniques (SW800) with a hand held enclosed applicator will be used. Flaming treatments will be performed by a handheld infrared flamer manufactured by Bruhwiler and Balterswil (Eco-Weeder Lady). Potential attractants for *T. luctuosa* will be applied to selected plots 15-30 days after weed control treatments, when field bindweed growth resumes, to target the late season biomass accumulation and to synchronize with the natural increase of moth population. Attractants will be band sprayed next to the crop row. Field bindweed plant density, coverage, and biomass will be recorded. Plots will be scouted for *T. luctuosa* presence and evidence of herbivory. Plant density also will be monitored the following year to compare with initial plant density. Crop evaluations will include plant injury and yield.

Objective 4. Report experience and discovery by cooperating producers and researchers as case studies and project summaries through e-Organic and traditional extension platforms and publications (all personnel with assistance from Brewer and Formiga)

The e-Organic program is a virtual workspace and community hub for farmers, ranchers, agricultural professionals, certifiers, researchers, and educators seeking reliable information. Content developed with e-Organic is collaboratively authored and peer-reviewed, and available for public viewing as well as via direct newsletter, which reaches over 12,000 people. By partnering with e-Organic, we will be able to utilize successful infrastructure already in place to best disseminate knowledge to both the regional and national organic community. (e.g. website development, webinars, etc.) to highlight the project, encourage participation, promote successful strategies, and discuss challenges and future directions.

****Progress**** 09/01/17 to 08/31/21

****Outputs**** Target Audience: Basic agricultural science researchers Applied agricultural science researchers Graduate students Producers of agricultural commodities

Changes/Problems: Nothing Reported

What opportunities for training and professional development has the project provided? A training guide has been developed for farm workers and growers, it is available on the e-Organic project site. This quick guide includes photos of each approved biological weed control agent, life cycles, sampling and evaluation protocols. An outreach event was conducted in collaboration with a local middle school and the OSU Linus Pauling Institute Healthy Youth Program. Field bindweed was overtaking a corner of the student garden. We assisted the teacher in developing plans for quadrat sampling. Each student (n=30) released *T. luctuosa* and made subsequent observations. Middle school students learned how to measure and document bindweed growth over time. They monitored the area, completed quadrat studies, created google sheets with cover percentages, analyzed data and documented their findings with photographs. As middle school students, there was quite a gradient in how involved they were in the project and how accurate their data were. Nevertheless, the Healthy Youth Program coordinator judged it to have been a solid learning experience for them. How have the results been disseminated to communities of interest? When the graduate dissertation is defended and published, we anticipate the publication of at least 2 journal articles for academic peers, and an additional methods paper about a lab rearing technique for *T. luctuosa*. Members of the research team have posted extensive project-related articles to the project's eOrganic website resources tab. <<https://eorganic.info/node/26425>> Some resources on the eOrganic tab will be adapted for publication by Oregon State University Extension Communications unit.

What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

****Impacts**** What was accomplished under these goals? (1) While we are not publishing the management plans developed and under implementation, we are sharing on the project website a visual description of the management plan creation and implementation process. (2) Field tests of attractants were conducted, and we have confirmed that certain semiochemical blends attract more moths than pheromones alone. The ratio of female moths in traps is still low, but work is ongoing as part of a graduate program study by our team. (3) We were able to confirm a bi-voltine activity pattern of *T. luctuosa* in the PNW region. These data support continued investigation of the integration of biocontrol with steam weed control, organic-approved herbicides, and other management tactics. (4) An extensive article about field bindweed management has been developed and is posted on the e-Organic website. It includes section headings for easy viewing by the reader: ecological management of bindweed, biological control, mechanical control, etc. and includes a full list of references.

****Publications**** - Type: Websites Status: Published Year Published: 2021 Citation: Look Alikes: FIELD BINDWEED VS. OTHER COMMON WEEDS Jessica Green, FRA, Dept HORT OSU <https://www.eorganic.info> - Type: Websites Status: Published Year Published: 2021 Citation: CREATE A BINDWEED MANAGEMENT PLAN FOR YOUR PROPERTY Linda Brewer, FRA Dept HORT OSU <https://www.eorganic.info> - Type: Websites Status: Published Year Published: 2021 Citation: Field Bindweed: Why its so hard to manage Jessica Green, FRA, Dept HORT OSU <https://www.eorganic.info> - Type: Websites Status: Published Year Published: 2021 Citation: Saturated Steam for Field Bindweed Management Moretti. <https://www.eorganic.info> - Type: Other Status: Published Year Published: 2021 Citation: Green, J. Biocontrol of Field Bindweed Research Summary. OSWS Annual Meeting. <https://www.eorganic.info> - Type: Websites Status: Published Year Published: 2021 Citation: Green, J. 2021. Integrated Management of Field Bindweed: Ecological Management Planning. <<https://www.eorganic.info>>. - Type: Other Status: Published Year Published: 2021 Citation: Organic Control of FBW in the PNW. J. Green, ML Moretti, L Brewer, A Formiga, M. Choi, RE Peachey <<https://eorganic.org/node/35047>>.

PROGRESS

2017/09 TO 2018/08 Target Audience: Basic agricultural science researchers, Applied agricultural science researchers, Graduate students, Producers of agricultural commodities, The public at large, Other - please specify. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Collaborating growers have toured the trials to learn about steam treatment performance and ease of operation. One master level student graduate student joined the project and is involved in research implementation, evaluation, and extension activities. Growers and industry members witnessed a demonstration of the steam technology at the 2018 Blueberry Field Day. Fifty-two participants in an Oregon Public School Grounds Employee IPM Training witnessed a technology demonstration on August 23, 2018, on a University farm. How have the results been disseminated to communities of interest? Results been disseminated to communities of interest through Extension field days, through individual farm visits, and through a meeting to discuss the project, lay foundations for case studies, and to enrich thinking and discussion about field bindweed management plans for each of the collaborating farms. What do you plan to do during the next reporting period to accomplish the goals? We will repeat the trials initiated in 2018, and develop an implementation cost analysis. At the end of calendar 2018, we will evaluate the performance of several organic weed management tools, alone or in combination at different time of the year, to inform growers on choosing management practices. We will continue to rear out *T. luctuosa* to support winter greenhouse studies. We will disseminate preliminary findings via eXtension webinar, and will continue to populate the project website with photos, written content, and a log of media attention.

2018/09 TO 2019/08 Target Audience: Basic agricultural science researchers Applied agricultural science researchers Graduate students Producers of agricultural commodities The public at large Changes/Problems: On-farm research was challenging at one of the large commercial farms. Poor communication between the fieldman and the weed control work crew led to the loss of all research plot data due to complete mechanical control. Therefore, release of larvae at this site was delayed until mid-August. One benefit to this 'mishap' is that we were able to monitor bindweed growth from bare soil; later release of larvae may prove to be a better approach. Powdery mildew started to appear on bindweed plots on 24-July and 14-August in the commercial field research plots. Direct effects of the plant pathogen on herbivory by larvae is unknown. However, it is a contributing factor of the general decline in host-plant quality. In fact, the appearance of powdery mildew is considered as producers to develop seasonal, integrated weed management plans for field bindweed. Areas of improvements or research were identified when demonstrating research to farm crew. Potential to apply steam in a narrower 10 inch swath vs the 20 inch swath currently tested. As the steam flow is constant, a smaller treatment area could permit faster treatment along the row in blueberry and thus reduce operation costs. Improve thermal heat transfer by adding certified organic adjuvants to water. In theory, increased viscosity should improve heat transfer with less energy. Change the orientation of the brush weeder from 45 degree angle in relation to the blueberry row to parallel to the shrub row. This could minimize risk of brush axle damage to the weed mat and increase effective brush treatment as the entire brush would spin parallel to the weed mat. What opportunities for training and professional development has the project provided? An undergraduate research technician developed a comparative weed ID guide for farm workers and producers to discern field bindweed from others weeds common in organic systems including: prostrate knotweed, sharp point fluellin, and others. This need arose from conversations with fieldmen and others who were not secure in their own weed identification skills. One-page versions of the ID guide were published in both Spanish and English and made available as laminated cards. Provided opportunity for two undergraduate students to pursue personal passion in insect husbandry and botany. Research assistant enrolled in a doctorate program to further explore the chemoecology between the target weed and insects involved in this project. Augerson, E. N., Moretti, M. L. "Evaluation of Thermal, Mechanical, and Chemical Weed Control in Organic Northern Highbush Blueberries (*Vaccinium corymbosum*) in Oregon." Western Society of Weed Science, Denver, CO. (March 13, 2019). Augerson, E. N., Moretti, M. L. 2019. A comparison of currently available weed management tools for certified organic Northern highbush blueberries (*Vaccinium corymbosum*) in Oregon's Willamette Valley," American Society of Horticulture Science Las Vegas, NV. (July 2019). Poster Presentation. Augerson, E. N., Moretti, M. L. "Weed control in blueberries: comparing thermal, mechanical, and chemical tools," Weed Science Society of America, New Orleans, LA. (February 14, 2019). Met with collaborators to present results and train their eight employees. Steam and brush weeders were lent to collaborating grower for testing. Hands on training of two graduate students, two student workers, on research assistant, in addition to growers. Weed Management strategies in organic perennial crops, North Willamette Horticulture Society, Salem, OR, January 16, 2019, (40 adult educational contacts) Research Updates in blueberries, Oregon Blueberry Commission Annual Meeting, Salem, OR, January 7, 2019, (40 adult educational contacts) Weed management options for certified organic blueberry operations - update of ongoing trials. Blueberry Field Day, Aurora, OR, July 17, 2019 (120 adult educational contacts) Demonstration weeding equipment to forty landscape managers during turfgrass field day at OSU Lewis Brown Farm. How have the

results been disseminated to communities of interest? A research summary of site-specific biocontrol efforts was distributed to each cooperating grower. An overall summary of biocontrol efficacy potential was posted on the e-Organic project page. Face-to-face meetings, field day demonstrations, or scientific meeting presentations. A website has been established. What do you plan to do during the next reporting period to accomplish the goals? Continual rearing of the BCA will occur throughout the next period. We are currently evaluating artificial diets as a potential aid to mass rearing. A lab bench trial will be performed to assess direct effects on BCA pupal development and depth of heat transfer from steam in a synthetic soil column. Adult moths will be exposed to varying compounds and pheromone formulations in a modified wind tunnel assay. Behavioral response will be recorded, as well as GC-MS profiles of tested compounds. Publish a peer-reviewed article on rearing procedures for *Tyta luctuosa*, report interim findings at regional research meetings March-April 2020, repeat weed field study spring 2020 and weed mimic study fall 2020. Continue updating archived webinars, project summaries, case studies and publications so that farmers, extension agents, other researchers, agricultural professionals and other stakeholders and the general public can be informed of the results.

2019/09 TO 2020/08 Target Audience: Basic agricultural science researchers Applied agricultural science researchers Graduate students Producers of agricultural commodities The public at large Extension field faculty Undergraduate students Changes/Problems: The steam equipment suffered significant damage over a two-week on-farm study, with water tank, igniter, and eventually the entire boiler requiring replacement at a cost of \$4,500+ in parts and labor alone. Replacement parts and lack of qualified technicians to repair equipment suspended research efforts for over six weeks. COVID shutdown in Oregon limited many outreach events, the stakeholder annual meeting, laboratory and field work. We are grateful that a no-cost extension has been granted so that we can accomplish the approved research objectives. What opportunities for training and professional development has the project provided? Participant growers were exposed to new approaches to bio control of weeds and emerging physical control technologies. Undergraduate students were able to pursue personal passions in insect husbandry and botany for a second year, and in doing so, became very capable in collecting field data and recognizing signs of *T. luctuosa* activity. A training guide with photos of the appearance of each life cycle, how to evaluate damage by *T. luctuosa* and the other approved control agent, *Aceria malherbae*, is being developed for farm workers and growers, based on this body of student work. How have the results been disseminated to communities of interest? University COVID shut down eliminated the annual stakeholder meeting and many planned outreach events. All extension events after March 2020 were canceled because of the pandemic. Presentations to academic peers at national conferences Talk at the 2019 Oregon Society of Weed Science in Hood River OR, October 30, 2019. Talk at the Pratum Coop winter meeting, January 27, 2020. What do you plan to do during the next reporting period to accomplish the goals? We will continue to rear *T. luctuosa* and may explore cooperation with state agencies to expand efforts to distribute *T. luctuosa* en-masse throughout the region. No commercial or agency source for *T. luctuosa* pupae currently exists to our knowledge. All planned laboratory trials of testing new attractant formulations will proceed as planned, with the resumption of research activities in University facilities. Exploration of the effect of cultural and chemical treatments on *T. luctuosa* will be explored to determine whether a truly integrated approach to bindweed management is feasible with organic practices of steam, approved herbicides, and biocontrol. Finalize case studies and give a project overview seminar in the Department of Crop and Soil Sciences, Oregon State University. Prepare manuscripts for publication and develop an extension publication

IMPACT

2017/09 TO 2018/08 What was accomplished under these goals? Objective 1 Gathered pesticide regimes data from growers, in preparation for fall and winter exposure tests of *T. luctuosa* to insecticides, and the response of field bindweed to herbicides labeled for field bindweed and approved for organic production systems. Site visits to 4 cooperating farms to inform about the biology and appearance of *T. luctuosa*, different life stages, estimated activity times, etc. Objective 2 Confirmed that benzaldehyde, although detected as part of the field bindweed semiochemical profile, does not attract *T. luctuosa*, and may in fact support a push/avoidance control strategy. Continuing to work with a wasp bait as a stimulant to *T. luctuosa* oviposition. Established contact with an Australian researcher who has an insect 'attractant' formulation. We will obtain and test this compound against *T. luctuosa* in a wind tunnel and on other behavioral assays. Four replications of trapping for adult moths to provide longitudinal ground truthing of activity periods of the adults and Growing Degree Day model in a naturalized, non-production agricultural setting. Objective 3 Developed standard rearing procedures of *T. luctuosa*, currently on the F4 generation. This has provided us with different life stages to experiment on/release, and is continues to be a major challenge of this work, especially since the regional Insectary rearing partner is uncertain whether they will continue rearing *T. luctuosa* due to staffing levels. Quantitative dataset of growth

parameters of field bindweed throughout the season, with/without exposure to *T. luctuosa* larvae, and in commercial vs naturalized settings Evaluation parameters of field bindweed growth include: % flowering, % cover of the patch, runner/strand measurements, and defoliation ratings Steam equipment was modified to best fit blueberry row spacing, and field tests were performed to ensure efficacy. Several improvements have been made to equipment set up including manufacture of a new applicator hood. We have defined optimum boiler temperature (250 ° F) and travel speed (0.25 mph) to achieve desired weed control. At 225 degrees F an increase in weed control was noticed, but below 200 degrees, no weed control was observed. Speeds up to 1.25 mph provided >95% weed mortality for field bindweed. We will repeat this work to evaluate optimum speed under other environmental conditions and weed spectra. A second split-plot study was initiated to compare steaming, brush weeder, and organic herbicides ammonium nonanoate and caprylic plus caprylic acid. A second application of the same treatments serves as the sub-plot. Initial results indicate that steam provided the greatest efficacy. Objective 4 Established project website with eOrganic: <<https://eorganic.info/bindweed>>.

****PUBLICATIONS (not previously reported):**** 2017/09 TO 2018/08 No publications reported this period.

2018/09 TO 2019/08 What was accomplished under these goals? GOAL 1: Conducted on-site trainings of weed and biocontrol agent (BCA) identification for producers and farm personnel. Many of the farm workers were unaware of differences between field bindweed and other, prostrate-growth weeds with arrowhead-shaped leaves. Showing producers what immature and adult biocontrol agents look like may help with assessment in the future. GOAL 2: Conducted wind tunnel assays to test behavioral response of adult moths to known compounds and pheromones. Deployed one sampling event of sticky traps in an area where the bindweed moth has naturalized, to test attractiveness of known compounds to adult moths. Attempted the same sampling protocol with a different trap method, since sticky traps kill all captured moths, and we are seeking a non-destructive way to estimate population densities over time. Light traps are ineffective for this species. An attempted modification of McPhail traps did not capture any *T. luctuosa*. Deployed baseline traps at 2 commercial sites, detected moths on traps placed in edge habitat and in organic hazelnut but none detected in blueberry. Goal 3: Successfully established a mass-rearing protocol for the BCA, and have had no major issues in F15+ generations. Rearing of the BCA is an essential component to eventual, large-scale implementation, and we are now, to the best of our knowledge, the only U.S. facility that is rearing the agent. Cold storage of reared pupae resulted in 90% survival. Summarized rearing efforts from the technician, in prep for a journal article. Released larvae at 3 commercial cooperator sites and evaluated survival after common production practices. Compared method of release (varying density, +/- enclosure within mesh bags) and subsequent effect on herbivory and bindweed growth reduction. Performed nested quadrat sampling at 4 sites to evaluate bindweed growth and effects of larval feeding. Parameters measured included flowering, shoot length, and visible signs of herbivory. Two large scale field experiments were conducted in commercial blueberry in transition to organic certification. The experiments compared steam, brush weeder, and the organic herbicides caprylic + capric acid and ammonium nonanoate to untreated control. Identified interaction between spring vs summer performance of treatments. One field trial using annual ryegrass and crimson clover as weed mimics to calculate steam dose required to kill weeds depending on plant size. 720 gallons of steam per acre provide 90% weed control. Results indicate steam and brush weeder are cost-effective weed controls. The organic herbicides tested did not provide consistent weed control and were 2-3 times more expensive than hand weeding. GOAL 4: Updates on weed management with high pressure steam and raising field bindweed moths have been posted on the eOrganic websites with research highlights and photos. Additional information will be made available once two years of data are collected; including formal case studies and summaries. ****PUBLICATIONS (not previously reported):**** 2018/09 TO 2019/08 Type: Journal Articles Status: Submitted Year Published: 2019 Citation: Green, J. Submitted. Field Monitoring for Establishment and Seasonality of *Tyta luctuosa*, a Biological Weed Control Agent of Field Bindweed (*Convolvulus arvensis*). Biocontrol.

2019/09 TO 2020/08 What was accomplished under these goals? Objective 1: Directly communicated with growers to advise on the importance of edge habitat for maintaining and encouraging *T. luctuosa* populations. A rearing protocol for *T. luctuosa* is now published on the e-Organic site to assist anyone wishing to rear and augmentatively release of *T. luctuosa* as a biological weed control agent. Other methods of redistribution from wild-caught populations are being discussed (collecting adults, shipping pupae, etc). Objective 2: Limited progress was made on this objective during the reporting period. Laboratory assays were planned for March through May 2020, in preparation for deployment summer 2020. Access to campus facilities was restricted at that time, and pupae remained in cold storage. We were, however, able to analyze data from the 2019 field season, and found some interesting interactions among the initial semiochemical attractants tested and other tactics used to attract moths. There was higher bindweed coverage by moths in plots that included benzaldehyde as part of the semiochemical bait treatment, regardless of what other factors were present (pheromone, augmented release of larvae, etc.). Objective 3: A large dataset was gathered from monitoring 3 commercial farms and 1 research farm

where moths have naturalized. Parameters measured included flowering, shoot length, percent cover, and visible signs of herbivory. Analysis of that data has proven useful for developing future release plans. For example, if larvae must be contained within mesh bags to focus herbivory, a 'terminal capacity' of 5 larvae per bag seems to be consistent across observations. Met with collaborators to present results and train employees. Equipment (steam and brush weeder) were lent to a collaborating grower for testing, following hands-on training. One large-scale field experiment was conducted in an organic commercial blueberry plantation. The objective was to document efficacy and operational pros and cons of steam when applied by the grower's staff. The steam was effective at killing weeds, but it requires a qualified operator to ensure equipment longevity. Additional experiments were conducted on university farms to evaluate the impact of boiler temperature and steam flow rate on weed control. We confirmed that 720 gallons per acre of 200 F saturated steam are required to achieve 90% control across multiple weed species. However, 250 F provided 95% control and biomass reduction. This work allowed us to identify optimum temperature and application volume for weed control. Objective 4: Experience at each of the cooperating farms has been summarized in preparation for developing case studies. We gleaned valuable information about each farm's willingness and ability to participate in the project. A general informative article about biological weed control is being developed and will be posted on e-Organic site. ****PUBLICATIONS (not previously reported):**** 2019/09 TO 2020/08 Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2020 Citation: Moretti, M. L. "Weed Control in organic blueberries," In Proceedings of the 2020 Weed Science Society of America (March 3, 2020). Maui, HI.

[↑ Return to Index](#)

Transitioning to Organic Forage Cropping Systems, an Integrated Research, Education and Extension Project in Middle Tennessee

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Performing Institution	MIDDLE TENNESSEE STATE UNIVERSITY, 1301 EAST MAIN STREET, MURFREESBORO, TENNESSEE 37132

NON-TECHNICAL SUMMARY

This project proposes to increase the sustainability and resilience of forage-based production systems in the middle Tennessee region by promoting the transition to organic forage systems and adaptation of management practices to observed and anticipated climate changes by posing and answering the following questions: How can scientists/producers design and manage organic-transitional forage production systems that could provide adequate productivity, quality, and economic benefits? How can this transition contribute to enhanced agroecological function, climate change mitigation (reduced GHG emission) and long-term conservation of soil systems? How will new knowledge be delivered to producers, educators, students, and other stakeholders to make them understand the opportunities and issues associated with organic transition and identify appropriate solutions? The middle Tennessee region is of particular interest because of the importance of forage production and organic agriculture in local economy and the representativeness and diversity of its forage agriculture in this dramatically changing climate and land use. The project will take advantages of existing research infrastructure and educational/extension collaboration to complete the following tasks: conduct field-based research in a partnership between stakeholders and scientists for better understanding of the influence of rotational and intercropping on greenhouse gas emission, crop yield, forage nutritive value, and soil health in integrated transitional forage systems; quantify and characterize water, greenhouse gas, and energy fluxes and dynamics under transitional forage agroecosystems; develop optimal management practices that optimize both agronomic/economic profitability and ecosystem function; develop an educational and outreach paradigm for efficient transfer of project findings to stakeholders and public individuals.

OBJECTIVES

Conduct field-based research and on-farm demonstrations in a partnership between stakeholders and scientists for better understanding of the influence of rotational and intercropping on greenhouse gas emission, crop yield, forage nutritive value, and soil health in integrated transitioning forage systems. Quantify and characterize how transitioning into organic forage management practices can affect the water, greenhouse gas, and energy fluxes and dynamics in predominant forage production agroecosystems of the fescue belt region. Develop optimal management practices that optimize both agronomic/economic profitability and ecosystem function in

transitioning forage production systems. Develop an educational and outreach paradigm for efficient transfer of project findings to stakeholders and public individuals. Organize training and extension efforts on the farming strategies, certification processes, and economic decision-making while transitioning to organic forage production systems.

APPROACH

Our plan is to conduct a multi-year, multi-disciplinary, and multi-institutional research, education, and extension project in Middle Tennessee. Our approach will involve the collection and integration of soil, crop, and atmospheric data along with economic analysis and extension effort across two transitional system studies (an integrated forage cropping system study and a large-scale forage agroecosystem comparison study). Particularly, the cropping system study will evaluate predominant and novel cool/warm-season, annual/perennial forage systems in Middle Tennessee; and the agroecosystem study will focus on the quintessential cool-season grass-based agroecosystems in the fescue belt region. Data and research findings from two studies will be compared, integrated and shared among scientists and producers in the state and will also be incorporated into pertinent courses offered by both institutions. For objective 1, a three-yr transitional forage cropping system experiment will be conducted at the UT Middle Tennessee AgResearch and Education Center in Spring Hill, TN, to evaluate 1) greenhouse gas emission; 2) forage yield, nutritive value, and economic return; as well as 3) soil health and quality of various organic transitioning forage production systems in Middle Tennessee. The design of the forage cropping system study will be based on communication with local producers, NRCS agents and established research trials from the project Co-PD (Dr. Nave). The soil type is Maury silt loam (a fine, mixed, active, mesic Typic Paleudalfs) with average long-term precipitation and temperature of 1,397 mm yr⁻¹ and 15°C, respectively. The whole dedicated plot will be managed according to the NOP-guidelines with large buffer zones (> 20 m) to adjacent plots, as the entire plot area will be transitioned to certified status at the end of the study. The experimental design will be a randomized complete block design with four blocks. Systems will include an annual forage crop rotation system (cool-season and warm-season grass-legume mixtures) and four perennial forage systems (cool-season and warm-season grass monocultures, or interseeded with legumes), totaling 5 treatments. The annual forage crop rotation system will be composed by double cropping winter wheat and Austrian winter pea (*Pisum sativum* L.) followed by double cropping sorghum-sudangrass hybrid and cowpea (*Vigna unguiculata*(L.) Walp.). The four forage perennial systems will include: tall fescue, bermudagrass (*Cynodon dactylon*(L.) Pers.), tall fescue interseeded with alfalfa (*Medicago Sativa* L.), and bermudagrass interseeded with alfalfa. Greenhouse gas emission, forage productivity and nutritive value, and soil physical and chemical properties will be measured based on established protocols used in previous research led by the project management team. For objective 2, a large-scale flux tower-based agroecosystem comparison study will be conducted at the MTSU Experiential Learning and Research Center in Lascassas, TN based on an established agroecosystem study conducted by the PD (Dr. Cui) to evaluate 1) CO₂, water vapor fluxes and energy balance; 2) greenhouse gas emission; 3) forage composition, production, nutritive value, and economic return; as well as 4) soil health and quality of an organically managed forage agroecosystem versus a conventionally managed agroecosystem. The research site is located on a Hillwood gravelly silt loam (12 to 20% slopes, Alfisol, thermic Oxyaquic Fraglossudalf) in the climatic transition zones of the middle Tennessee region. Two quintessential cool-season (Tall fescue, Kentucky bluegrass, and Orchardgrass) dominated agroecosystems (1 hectare each) will be used. Both pastures have been established for more than three years and primarily used for hay production and periodical animal grazing. Botanical composition was evaluated between two systems in late 2016 and indicated no-significant difference in primary cool-season grass composition (tall fescue, 40%; kentucky bluegrass, 10%; orchardgrass, 20%; other forbs and legumes, 30%). Forage crop management, forage productivity and nutritive value, soil physical and chemical properties, and flux-tower based ecosystem measurement and greenhouse gas emission will be measured based on established protocols used in previous research led by the project management team. A key objective of this study is to determine the cost of transitioning from conventional forage production to organic forage production. Additionally, determining the annual cost of organic production once the transition phase is complete is integral. Partial budgeting will be used to compare conventional and organic production costs. Similarly, a sensitivity analysis will be performed on key cost categories that are identified through the field work. Forage production data will be used to estimate and compare the number of cattle grazing days and potential beef production in the organic system as well as the conventional forage production system. This will provide a method to estimate a break-even price for the organic system. We will develop educational materials and outreach events to communicate our research findings to Tennessee livestock and forage producers interested in transitioning to organic or already certified in the second and the third year of the project. We expect that producers will learn from the information delivered by this project and eventually adopt organic management practices to gain better organic forage yield and produce high-quality livestock. To achieve this goal, a comprehensive, multifaceted education and extension program will be implemented properly throughout the project duration period. **Progress** 09/01/17 to 08/31/21 **Outputs** Target Audience: The forage cropping

system team has completed all tasks during last year of this project, which included completion of field experiments, completion of sample collection and analysis, and presenting key findings at professional meetings. The target audience were graduate students, technical staff, forage and livestock researchers and scientists, and forage producers and extension agents. The efforts for this reporting period included completion of all sample analysis, field practice experiences, classroom instruction, outreach and services including thesis defense on the subject, formal project instruction and professional meeting presentations given by supported faculty members and graduate students. The main target audiences for the soil science team include organic farmers and farmers who are interested in transitioning from conventional farming to organic farming. Our target audiences also include students and researchers from agronomy and soil science communities who are interested in organic forage production and soil health and also consumers who are interested in organic livestock products. Across the entire duration of this project, one of the most important target audience groups was the project research team across two institutions. Both teams had collaboratively established, maintained, and gathered data from two research plots and completed the transition/organic certification processes. We have successfully supported one MS student (Mr. Kubesch) and one Post-doctoral associate (Dr. Xu) at the University of Tennessee. Several undergraduate student assistants were recruited throughout the duration of the project period. Meanwhile, the integrated teaching component focusing on organic forage production has been incorporated into several courses offered at MTSU. A large number of undergraduate students had witnessed how a systematically designed field study was conducted and how organic forage systems could become sustainable. All project PD/Co-PDs as well as graduate student and Post-doctoral research associate have delivered many presentation and conference poster at several regional and national conferences, such as the American Society of Agronomy Annual Conference and the Southern ASA conferences during the project period. This ensures the important research findings could be communicated well to the entire scientific community. At the same time, several outreach events have been conducted at the beginning years of the project, however, the COVID pandemic greatly limited the extent and frequency of outreach events that could be targeted towards producers and the general public. From the extension and outreach side, the target audiences include livestock and forage producers, producers considering transitioning to organic livestock and forage production, and other professionals in the field. After short discussions with producers, it is evident that many livestock producers utilize many organic forage production practices or lack of conventional forage production practices. This means many producers would not be faced with as severe of a challenge when converting land to organic production. In other words, these producers when not suffer forage yield loss due to not providing an inorganic fertilizer or succumb to weed pressure, they do not utilize inorganic fertilizer or chemicals to suppress weeds. This is an important target audience in that many livestock producers are technically producing organic forage without being certified, and they need assistance with extending this to the livestock production system. Thus, this group was identified as a key audience. Changes/Problems: There were no changes or problems encountered during the last reporting period. Overall, from the beginning of the project, the field experiment was delayed by 8 months in 2018 due to difficulties in establishing organic bermudagrass and alfalfa. Eventually, we were able to overcome these issues and successfully conduct the research for two consecutive years. Additionally, the COVID pandemic greatly limited the extent and frequency of outreach events that could be targeted towards producers and the general public. There were no other issues or changes to report. What opportunities for training and professional development has the project provided? In 2018, graduate students and field staff had the opportunity to advance their knowledge in forage establishment and management transition from conventional to organic production. Training has included literature review and one-on-one conversations with faculty members involved in this project. In 2019, training activities included graduate students and field staff learning more about organic forage production through hands-on practices, literature review and one-on-one conversation with their mentors. Professional development included two University of Tennessee Plant Science Department seminars were presented to show preliminary results from this project, and one conference presentation at a professional meeting. In 2020, we had completed several conference/professional meeting presentations. We have also completed a thesis, and more than five manuscripts that were submitted by the end of the field trial. Dr. Sutie Xu, a postdoc partially supported by this funding, received rigorous training from project PIs on organic farming practices as well as to conduct field and lab-based research. She was also given opportunities to gain analytical skills, mentor undergraduate and graduate students, publish findings, and develop ideas for grant proposals. Her involvement in this project for two years played a great role for her to secure a tenure-track Assistant Professor position. Two undergraduate students (Michael Russell and Sydney Logwood), partially supported by this grant, have been trained by PI Jagadamma on soil sampling and laboratory soil analysis in the last year of the project. Meanwhile, numerous undergraduate students have been recruited in the previous years at both UTK and MTSU to gain hand-on experience on forage planting, sampling, and analysis. How have the results been disseminated to communities of interest? Results have been disseminated through professional presentations, field day presentations, publications including scientific publications, a thesis completed on the topic, and producer forage field day showing Southeastern producers first-hand data from our project. The outreach component of this project along with most projects was severely hindered due to the COVID19 pandemic. The pandemic also

resulted in a considerable amount of outreach focusing on the impacts of COVID19. However, information concerning organic forage production economics was presented at more than ten individual meetings with more than 500 total participants including producers and other livestock and forage professionals within the duration of the project period. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

****Impacts**** What was accomplished under these goals? Conduct field-based research and on-farm demonstrations in a partnership between stakeholders and scientists. The field study at the Middle Tennessee AgResearch and Education Center, in Spring Hill, TN indicated that botanical composition fluctuated as a consequence of establishment dynamics and weed competition. Weed competition ranged from 200 to 800 g kg⁻¹ in the perennial swards, and variably affected forage quantity and quality. Nutritive value was sufficient for most livestock operations across treatments, with average crude protein of all treatments remaining ~150 g kg⁻¹ across two growing seasons. The annual rotation was the highest-yielding treatment, producing more than 6 Mg ha⁻¹, though tall fescue and tall fescue-alfalfa produced (~4 Mg ha⁻¹) without associated establishment concern. For transitioning organic producers, the annual rotation, tall fescue, or tall fescue mixed with alfalfa treatments might best serve their operations contingent on weed competition and establishment concerns. The research data from the MTSU site indicated that annual systems had the greatest productivity (12.7 Mg ha⁻¹) followed two perennial systems, including old world bluestem-sainfoin (11.3 Mg ha⁻¹) and bermudagrass-alfalfa (10.3 Mg ha⁻¹) bicultures. Annual system also indicated limited nutritive value advantages, low mineral concentration, and poor economic return due to annual cultivation and high labor input. Perennial systems, particularly old world bluestems-based bicultures, indicated great adaptation, radiation use efficiency, and soil carbon contribution. Monthly initiation biomass greatly affected several nutritive value indices ($P < 0.05$, $R^2 \approx 0.5$) within many forage systems. We concluded that, under organic forage production, annual systems could offer excellent yield and biomass production. However, in the long run, perennial bicultures would lead to better economic return and ecological benefits. Soil results showed that perennial mixtures have greater potential to improve soil health than monocultures, especially total nitrogen, total organic carbon, and mineral nitrogen. Annual mixtures also improved soil organic carbon and total nitrogen, but had some undesirable effect on soil properties including decreased extractable potassium. Soil microbial biomass carbon changed with season and was more sensitive to the weather in each year than the species compositional changes. The soil health team also conducted a laboratory microcosm experiment to understand the climate resiliency of soils under organic management. Results showed that soil respiration from organic pasture system was more sensitive to wet/dry cycles, while that from conventional pasture system was more sensitive to temperature changes. The effect of wet/dry cycle on soil respiration was greater at higher temperatures, and the temperature sensitivity was greater under wet/dry cycles than constant moisture conditions. We also found that microbial biomass carbon was positively correlated to respiration, and negatively related to Q10. Quantify and characterize how transitioning into organic forage management practices can affect the water, greenhouse gas, and energy fluxes and dynamics in predominant forage production agroecosystems of the fescue belt region. A large organic pasture forage system was investigated in this project to better understand its productivity as well as the dynamics of net ecosystem exchange (NEE) and hydrological responses (e.g. evapotranspiration, ET). Throughout the duration of this study, the entire pasture ecosystem remained a strong carbon sink, with the NEE fluctuating from -1.2 to -1.9. The cumulative ET was around 750 mm per year; and the overall ecosystem water use efficiency (EWUE) were calculated as 61 g C kg⁻¹ water across all growing seasons. Overall, under organic forage production, warm-season vegetation encroachment in the summer could result in greater forage biomass production leading to greater cumulative NEE and EWUE on a system level, compared with commonly fertilized cool-season pasture systems (tall fescue and/or orchardgrass-based pastures). Well managed defoliation and interseeding of legumes should be encouraged to maintain adequate nutritive status. Forage production summer slump was not observed on the large pasture field mainly due to the warm-season encroachment. Managing cool-season pastures organically could result in greater carbon sequestration potential and soil health benefit in the long run. Develop optimal management practices that optimize both agronomic/economic profitability and ecosystem function in transitioning forage production systems. As indicated in our results, economic benefit and output-to-input ratio varied greatly across different forage systems. Despite greater yield and output value, annual systems incurred huge seed costs (near 20% of the total input cost), and much greater repair and labor costs compared to perennial systems due to the requirement on annual planting, harvesting, and tillage; thus, resulting in negative profit on a system basis. Across all treatments, seeds, labor, repair, and fuel costs represent the top-ranking cost categories for production input. Additionally, a fixed rate organic inspection cost was used for all treatments due to our small-plot setting. We anticipate that the actual per-hectare cost should be much lower leading to better profitability on much larger production scales. Despite slightly higher seed costs, warm-season grass-based systems clearly indicated better economic profitability compared to cool-season-based systems largely due to greater yield. We believe the true economic return should be greater if organic producers are willing to diversify their field operation and product delivery instead of organic hay alone (e.g., produce certified forage seeds, beef cattle, dairy products). Develop an educational and outreach paradigm for efficient transfer of project findings to stakeholders and public individuals. Organize training and extension efforts on the farming strategies, certification

processes, and economic decision-making while transitioning to organic forage production systems. The initial outreach and Extension programming has begun through a program entitled Managing Forage Risk in the Mid-South led by Dr. Griffith in 2018. This program addresses many of the risks faced by forage producers and some strategies to reduce or eliminate those risks. Many of those strategies are more closely related to organic forage production than conventional forage production though the management strategies can be adapted to either system. In the second and the third year of the project, Dr. Griffith has continued the information dissemination effort through various Outreach and Extension programming sponsored by the UTIA, but mainly continues through the Managing Forage Risk in the Mid-South Program. Additionally, Dr. Griffith has been working with a few producers on an individual basis to enhance organic forage production through grazing practices. Dr. Griffith also presented economic data and focused on using research data to construct transition and maintenance budgets for organic forage production. In doing this, this helped producers better understand the risks, challenges, and costs of transitioning to organic forage production. At the same time, we calculated the cost of production on a forage yield and nutritive basis which will provide a pure estimate of costs to forage and livestock production; and continued to work with individual producers who are establishing or reestablishing forages and how to reduce costs throughout the life of the forage stand. The notable accomplishments are with producers who have successfully converted to organic forage production. However, other notable accomplishments are producers who did not convert to organic production, because it was not suitable for their management and financial well-being.

****Publications**** - Type: Theses/Dissertations Status: Published Year Published: 2020 Citation: Kubesch, Jonathan, "Forage species selection for transitional organic production in the Southeastern United States." Master's Thesis, University of Tennessee, 2020. https://trace.tennessee.edu/utk_gradthes/5844

- Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Griffith A.P. Top Money Eaters in Cow-Calf Production. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Griffith A.P. Budgeting Freezer Beef Production. - Type: Journal Articles Status: Published Year Published: 2021 Citation: Griffith, A.P. 2021. Making Money in the Spring and Summer with Cattle. Tennessee Cattle Business, May - Type: Book Chapters Status: Published Year Published: 2021 Citation: Xu, S., Jagadamma, S., Oakes, R.N., Cui, S., Byers, E., and Li, Z., 2021. Potential and Challenges of Growing Cover Crops in Organic Production Systems. In: Cover Crops and Sustainable Agriculture, Islam, R., and Sherman, B (Eds.), CRC Press, A Science Publishers Book. p 28-40. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Jagadamma, S., Xu, S., Oakes, R., and Cui, S. 2020. Forage production and soil health in organic forage cropping systems. UT Beef and Forage Center Meeting (Oral-Invited), December 15. Virtual (presenting author is highlighted) - Type: Journal Articles Status: Under Review Year Published: 2021 Citation: Xu, S., Jagadamma, S., Oakes, R.N., and Cui, S. Soil health is affected by species compositional changes in organic forage systems in southeastern USA. - Type: Journal Articles Status: Under Review Year Published: 2021 Citation: Li, Z., S. Xu, N. Rajan, S. Nair, S. Jagadamma, R. Nave, J. Kubesch, G. Bates, D. McIntosh, and S. Cui. Productivity and Nutritive Value of Five No-input Certified Organic Forage Cropping Systems with Minimum Tillage. - Type: Journal Articles Status: Under Review Year Published: 2021 Citation: Xu, S., Jagadamma, S., and Cui, S. Soil organic carbon cycling in response to increased temperature and wet/dry cycles in organic and conventional forage production systems. - Type: Journal Articles Status: Under Review Year Published: 2021 Citation: Kubesch, J.O.C.*, R.L.G. Nave, S. Cui, G.E. Bates, D.M. Butler, and V. R. Pantalone. 2021. Forage species selections for transitional organic production in the Southeastern United States. Agron. J. - Type: Journal Articles Status: Under Review Year Published: 2021 Citation: Kubesch, J.O.C.*, R.L.G. Nave, A.P. Griffith, S. Cui, G.E. Bates, D.M. Butler, and V.R. Pantalone. 2021. Economic outcomes of cool and warm-season swards in transitioning organic swards. Agron. J. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Griffith A.P. Beef and Forage Production Resources. - Type: Journal Articles Status: Published Year Published: 2020 Citation: Griffith, A.P. 2020. Fescue Hay in May and Pasture Thoughts. Tennessee Cattle Business, May. - Type: Journal Articles Status: Published Year Published: 2019 Citation: Griffith, A.P. 2019. Drought: Don't Give Up All Over Again. Tennessee Cattle Business, November. - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Kubesch, J., R.L.G. Nave, S. Cui, G. E. Bates, and D.M. Butler. 2020. Seeing the forage through the weeds: weed competition in transitioning organic systems. International Annual Meetings ASA-CSSA-SSSA Virtual. - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Kubesch, J., and R.L.G. Nave, S. Cui, A. Griffith, G. E. Bates, and D.M. Butler. 2020. Optimal forage species selection for southeastern transitional or low-input production. 2020 American Forage and Grassland Council Conference Greenville/SC. - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Xu, S., Jagadamma, S., Oakes, R.N., and Cui, S. 2020. Soil Health Influenced by Forage Composition in Organic Systems. ASA-CSSA-SSSA International Annual Meeting. Virtual meeting. November 9-11, 2020 - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Xu, S., Jagadamma, S., and Cui, S. 2020. Temperature and Wet/Dry Cycles Effects on Soil Organic Carbon Dynamics under Organic Forage Farming. ASA-CSSA-SSSA International Annual Meeting. Virtual meeting. November 9-11, 2020 - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Kubesch, J., R.L. Nave,

G.E. Bates, S. Cui, and D.M. Butler. 2019. Forage species selection for transitional organic production in Middle Tennessee. ASA-CSSA-SSSA, San Antonio, TX, Nov. 10-13. - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Cui, S. 2019. Modeling CO₂ and H₂O from a cool-season dominated native prairie in the climate transition zone of the U.S. ASA-CSSA-SSSA, San Antonio, TX, Nov. 10-13. - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Kubesch, J. 2020. Optimal forage species selection for southeastern transitional or low-input production. AFGC, Greenville, SC, Jan. 5-8. - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Kubesch, J. 2019. Forage species selection for southeastern transitional or low-input production systems. UT Beef and Forage Center Research and Recommendation Meeting, Knoxville, TN. Dec. 17. - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Griffith A.P. Top Money Eaters in Cow-Calf Production. Tennessee Forage and Grassland Conference, 2019. - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Griffith A.P. Tennessee Master Small Ruminant: Forage Risk. Tennessee Master Small Ruminant Producer Program. 2019. - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Griffith A.P. Tennessee Advanced Master Beef Producer: Marketing and Management, Forage Risk. 2019. - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Griffith A.P. Economics of Hay of Different Quality. 2019. - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Griffith A.P. Grass Fed Beef Operations: Economics and Considerations. - Type: Journal Articles Status: Published Year Published: 2019 Citation: Griffith, A.P. Pasture, Rangeland and Forage Insurance as a Risk Management Tool. University of Tennessee Extension Publication W 343. - Type: Journal Articles Status: Published Year Published: 2019 Citation: Jagadamma, S., Essington, M.E., Xu, S., Yin, X. 2019. Total and Active Soil Organic Carbon from Long-term Agricultural Management Practices in West Tennessee. *Agricultural & Environmental Letters*, 4(1).180062 - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Jagadamma, S., Essington, M.E., Xu, S., Yin, X., Long-term Impacts of Cropland Management on Depth Distribution of Soil Organic Carbon in West Tennessee. ASA Southern Regional Branch Annual Meeting, Birmingham, AL, February 3-5, 2019. - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Menefee, D., N. Rajan, and S. Cui. 2019. Growth stage specific evapotranspiration measurements using eddy covariance compared to DSSAT evapotranspiration simulation for dryland corn and cotton in Southern-central Texas. ASA-CSSA-SSSA, San Antonio, TX, Nov. 10-13. - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Menefee, D., N. Rajan, S. Cui, S. Shafian. 2019. Estimation of gross primary for cotton and corn using high resolution planetscope satellite data. ASA-CSSA-SSSA, San Antonio, TX, Nov. 10-13. - Type: Conference Papers and Presentations Status: Published Year Published: 2019 Citation: Cui, S. 2019. Carbon and water vapor flux dynamics of major forage and row-crop systems in the Southern U.S. under changing climate conditions. Invited Presentation at the University of Tennessee Institute of Agriculture Climate Change Adaptation: Cover Crop and Irrigation Field Day, March 29, Spring Hill, TN (invited presentation).

PROGRESS

2018/09 TO 2019/08 Target Audience: During the second reporting period of this project, our major target audience was the research groups at both institutions. The project management team has recruited several undergraduate students to assist with field data collection and preliminary laboratory data processing/analysis. We have completed the organic certification processes working with the QCS Certification Services. Both the small forage cropping system plots and the large forage agroecosystem plots at MTSU have already been organically certified and will continued to be certified on a yearly basis. The small-plot field at UTK has been certified as organic transitional plots. At MTSU, students from two classes (ABAS 2210-Introduction to Agricultural Engineering; and PLSO 4310-Forage Crops) had participated the field day tours at the research plots. During classroom teaching, we have covered concepts, policies, and practice guidelines associated with organic/transitional forage production nationwide. The forage cropping system team at UTK group led by Dr. Nave has continued collecting forage biomass and nutritive value data from the small-plot forage cropping system study at the UT Middle Tennessee AgResearch and Education Center in Spring Hill, TN. The main targeting audience included graduate and undergraduate students, extension agents and producers. Efforts included informal educational programs such as internships, workshops and extension activities. Our soil team leader, Dr. Jagadamma has continued her work centering the soil health component affected under both conventional and transitional approaches. The main target audiences include individuals, stake holder groups, market segments, or communities that are particularly interested in the benefits of transitional/organic forage management approaches on soil health. Dr. Jagadamma also recruited undergraduate student assistants that are racial and ethnic minorities and those who are socially, economically, or educationally disadvantaged. The primary target audience group for our Extension team led by Dr. Griffith includes forage and livestock producers that have already transitioned or are currently considering to establish economically sustainable organic forage systems in the future. Particularly, through field visits with producers and personal interactions with the general public during the

Extension events, Dr. Griffith has identified that consumers have provided greater demand for organically produced food items as well as other products. The organically grown food items that tend to be more readily available to consumers include fruits, vegetables, and food products with a short production horizon and a relatively short list of inputs. However, organic forages, beef cattle, and dairy products, which have a longer input production list, have gradually gained market share on the agricultural isle. It can be difficult to identify and establish all the necessary relationships with input suppliers for organically produced livestock products. A key component on that list involves forage which will compose the majority of a nutrition plan for cattle, sheep, and goats. Thus, the target audience of this project has been cattle, sheep, and goat producers who are producing animal products and meat protein for sale. Additionally, another audience has been forage producers who desire to market organically produced hay to organic livestock producers. An issue that some producers have faced is over producing for the organic market and then having to market the remaining production at commodity prices. This is not a major concern due to the small scale most are working from, but it could become one if production is increased. Changes/Problems: Most team members do not anticipate major changes or problems during this reporting period. What opportunities for training and professional development has the project provided? At MTSU, a Plant and Soil Science major student Mr. Andrew Nevins is currently assisting in forage/soil sampling, plot maintenance, and collection of the eddy covariance flux-tower data. Around 55 undergraduate agricultural students in MTSU School of Agriculture have taken classes incorporated with field demonstration of transitional forage production as well as advanced instrumentation usage in monitoring greenhouse gas emission in agricultural fields. Additionally, Dr. Nate Phillips has organized several field trips hosted by local NRCS Soil Conservationists to teach students the concepts of cover cropping, organic farming, and soil health. Additionally, many project collaborators from NRCS have visited and guest-lectured in several courses offered by Drs. Cui and Phillips. At UTK, graduate student training involves conducting and assisting research activities related to forage quality analysis using NIR, forage phenotyping, as well as preliminary data summary and statistical analysis. Within Dr. Jagadamma's group, a postdoc (Sutie Xu), partially supported by this funding, has been trained in writing manuscripts and grant proposals, conducting field and lab experiments, and operating instruments such as TOC analyzer. She has been given opportunities to mentor undergraduate and graduate students, deliver guest lectures, attend conferences, and interact with organic producers. An undergraduate student (Michael Russell), partially supported by this funding, has been trained by Sutie Xu and Sindhu Jagadamma on soil sampling and laboratory soil analysis. How have the results been disseminated to communities of interest? During the second year of this project, information concerning organic forage production economics has been presented at 10 individual meetings with 452 total participants. The organic forage economics program has been designed to educate producers about risk management in forage production, reducing input costs, and the cost of low quality forage. What do you plan to do during the next reporting period to accomplish the goals? Both research group at MTSU and UTK will seek to continue monthly sampling as well as maintain fertility schedule. Mr. Kubesch (the M.S. student supported by this project) will complete his thesis draft in summer of 2020. Additionally, Dr. Renata together with Dr. Griffith will give numerous Extension presentation to distribute the findings from this research to various stakeholder groups in Tennessee. Jagadamma lab will continue conducting biannual soil health measurements. By the end of next reporting period (August 2020), we will have summarized the soil health changes and presented the results in an international conference and begin the process of writing a manuscript. We will also complete a laboratory microcosm experiment to understand the residue decomposition potential of organic and conventional soils under different climate change scenarios. Our research team is currently working on several scientific publications that should be submitted within the first quarter of 2020. Particularly, we have analyzed the Eddy Covariance-based flux tower data from those two large forage ecosystems before the organic certification was completed. The post-certification data have been recorded and will be compiled and compared with previous years' data. We will continue collecting high-intensity forage nutritive and biomass data across both institutions and will keep tracking soil health data. From an Extension and outreach standpoint, the plan is to continue working with the physical scientists to collect production data and use that data for economic analysis that can then lead to more organic forage program outreach efforts as well as lead to scientific journal publications. 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outreach standpoint, the plan is to continue working with the physical scientists to collect production data and use that data for economic analysis that can then lead to more organic forage program outreach efforts as well as lead to scientific journal publications. From an Extension and outreach standpoint, the plan is to continue working with the physical scientists to collect production data and use that data for economic analysis that can then lead to more organic forage program outreach efforts as well as lead to scientific journal publications.

2019/09 TO 2020/08 Target Audience: For the current reporting period, several undergraduate students have completed field data collection at MTSU Experiential Farm Laboratory and at the UTK Middle Tennessee AgResearch and Education Center (MTREC) in Spring Hill, TN. The project management team has been working closely with a Master's Degree Student fully supported by this project and a postdoctoral research associate partially supported by this project. The onset of COVID-19 has greatly affected the information dissemination to the general public and the scientific community. However, several virtual conferences as well as Extension events have been organized by professional societies and the institutional network to ensure the broader outreach of the information delivery. For the 2019 semester, students from two classes (PLSO 3330-Introduction to Field Crop Production and PLSO 4310-Forage Crops) had visited the research plots. As the main instructor for these courses, Dr. Cui has continued covering concepts, policies, and practice guidelines associated with organic/transitional forage production and cropping system design. The UTK group led by Dr. Nave has continued collecting forage biomass and nutritive value data from the small-plot forage cropping system study at the MTREC in Spring Hill, TN. The main targeting audience included undergraduate and graduate students, research faculty, scientist, extension county agents and forage/beef cattle producers in the state. Our soil health team leader, Dr. Jagadamma has continued her work centering the soil health component affected under both conventional and transitional approaches at both research locations (MTSU and UTK sites). In addition to supervising a postdoctoral research associate with expertise in soil science and soil physicochemical property analysis, Dr. Jagadamma also supervised several undergraduate students in the past year. For the Extension component of this project led by Dr. Griffith, the target audience during this reporting period started out with the traditional organic livestock and forage producers and those producers who were considering transitioning to organic livestock and forage production. However, the direction was quickly changed with the onset of COVID-19. As the impacts of COVID-19 spread, cattle began to back up in traditional marketing channels due to a slowdown in harvest. As harvest slowed down so did meat production which resulted in less meat product being available at grocery stores. This put consumers on the hunt for meat and much of that came back to the farm level. Thus, many meat consumers are looking for meat products directly off the farm which in turn means a change in production practices for livestock producers. The primary changes and challenges were keeping animals on the farm longer as well as feeding those animals. Many producers and consumers were looking for a grass-based product and this included organically produced product. A producer cannot convert to organically pastured livestock as quickly as the demand surfaced. Thus, the questions became more about high-yielding and high-quality forages to grow livestock on to meet consumers' demand. This particular instance may result in more producers transitioning pastures to organic production in the coming years. Changes/Problems: We will present the field data on the April-November window rather than year-round data (in order for month-by-month comparisons, and verisimilitude of use in the field). Additionally, our team will produce herbarium specimens of the weed species present to evaluate weed shifts, and quantify the weed legume presence in terms of N contribution/credits. Finally, the project team has already completed the non-cost extension for another year to allow more preparation time for both Dr. Xu and Mr. Kubesch to publish the collected results in peer-reviewed journals. Most team members do not anticipate major changes or problems during this reporting period. What opportunities for training and professional development has the project provided? At MTSU, more than 40 undergraduate agricultural students in the MTSU School of Agriculture have taken classes incorporated with field demonstration of transitional forage production as well as advanced instrumentation usage in monitoring greenhouse gas emission in agricultural fields. Our field-trip based activities have been largely suspended due to the COVID-19 pandemic. For Dr. Nave's group, this project has allowed investigators to train and develop various professionals, including research associate staff (Mr. David Plunk), undergraduate international students interns, and M.S. student (Mr. Kubesch), who is currently responsible for conducting the research, collecting samples and conducting field work, statistical analyses and thesis writing. In Dr. Jagadamma's team, Dr. Sutie Xu, a postdoc partially supported by this funding, has been trained to conduct field and lab-based research. She has also been provided with opportunities to gain analytical skills, mentor undergraduate and graduate students, publish findings, and develop ideas for grant proposals. An undergraduate student (Michael Russell), partially supported by this funding, has been trained by Sutie Xu and Sindhu Jagadamma on soil sampling and laboratory soil analysis. How have the results been disseminated to communities of interest? At the 2019 University of Tennessee Fall Forage Field Day, Dr. Nave served as a member of the MTREC delegation and presented the results from the field component to various educators, Extension agents, faculty members, and students mainly from the UTK. She also delivered a similar presentation at the University of Tennessee Dairy Research and Education Center at Lewisburg, TN. For the Extension component, information concerning organic forage

production economics has been presented at 12 individual meetings with 740 total participants. The organic forage economics program has been designed to educate producers about risk management in forage production, reducing input costs, and the cost of low quality forage. What do you plan to do during the next reporting period to accomplish the goals? For the next reporting period, we plan to have successfully completed two full years of research data at MTREC fully analyzed and compiled. We aim to complete M.S. student's thesis, present final findings of the project in professional scientific meetings and extension meetings. Also, we plan to have submitted two or three manuscripts for peer-reviewed scientific journals. Dr. Jagadamma's lab will finish the last set of soil health measurements. We will also complete the laboratory microcosm experiment by analyzing soil enzyme activities. By the end of the next reporting period (August 2021), we will publish two manuscripts as lead authors from this project. From an Extension and outreach standpoint, the plan is to continue working with the physical scientists to collect production data and use that data for economic analysis that can then lead to more organic forage program outreach efforts as well as lead to scientific journal publications. The analyzing of data from an economic perspective is in process as Dr. Griffith continue to work with the graduate student to fulfill his requirements for a Masters' degree.

IMPACT

2018/09 TO 2019/08 What was accomplished under these goals? Conduct field-based research and on-farm demonstrations in a partnership between stakeholders and scientists for better understanding of the influence of rotational and intercropping on greenhouse gas emission, crop yield, forage nutritive value, and soil health in integrated transitioning forage systems. Both research plots at MTSU has already been organically certified. We have continued collecting forage nutritive data, forage biomass data, soil and weed survey data. The first year's nutritive data has already been analyzed using the NIRS. Additionally, leveraging support from another USDA funded program and another MTSU internal grant program, Dr. Cui at MTSU has purchased an NIRS system in conjunction with the annual access of the NIRS Forage and Feed Testing Consortium's Prediction Equation Database. This will enable fast-and-easy testing of forage nutritive value following harvesting. Dr. Renata's group at UTK has been collecting monthly forage quality and quantity samples for evaluating forage mass, botanical composition, and nutritive value. Summer weed surveys were conducted in July of 2018 and 2019. Organic Boron fertilizer was applied to all alfalfa plots, and manure fertilizer was applied to tall fescue monoculture and bermudagrass plots according to soil testing in early March and April of 2019, respectively. Soil sampling was performed in October of 2018 and June of 2019. Pertaining to the first goal, Dr. Jagadamma's lab investigated soil health changes under different organic forage management. The team has been conducting soil sampling on biannual basis for the analysis of soil health parameters. Preliminary results showed that organic forage management improved soil health parameters. For example, soil pH, inorganic N, Ca, K, Mg, Na, and P were increased at the top 15 cm depth compared to conventional forage system. In addition, soil properties in the surface layer of organic systems were influenced by the forage species. However, soil properties below 15 cm depth were not greatly influenced by the management changes in 1.5 years. Quantify and characterize how transitioning into organic forage management practices can affect the water, greenhouse gas, and energy fluxes and dynamics in predominant forage production agroecosystems of the fescue belt region. Both eddy-covariance systems (one on a conventional forage ecosystem, another on a certified system) have been functioning properly and are continuously logging water, greenhouse gas, and energy fluxes data. A fully integrated solar-powered mobile trailer unit that could safely house the trace gas analyzer during in-situ measurement has already been fully assembled and deployed in the small-plot research field. The entire system is simultaneously quantifying soil greenhouse gas emission from 12 different plots. Develop optimal management practices that optimize both agronomic/economic profitability and ecosystem function in transitioning forage production systems. The research team across both institutions is currently compiling research data from both locations in Middle Tennessee across both large and small plot systems that could be used for provide valuable managerial information for organic and transitioning producers. Develop an educational and outreach paradigm for efficient transfer of project findings to stakeholders and public individuals. Organize training and extension efforts on the farming strategies, certification processes, and economic decision-making while transitioning to organic forage production systems. During this reporting period, Dr. Griffith has continued the information dissemination effort through various Outreach and Extension programming sponsored by the UTIA, but mainly continues through a program entitled Managing Forage Risk in the Mid-South. This program addresses many of the risks faced by forage producers and some strategies to reduce or eliminate those risks. Many of those strategies are more closely related to organic forage production than conventional forage production though the management strategies that can be adapted to either system. Another accomplishment has been working with a few producers on an individual basis to enhance organic forage production through grazing practices. These producers are not necessarily focusing on organic forage production but rather low cost forage production. In making this transition,

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2019/09 TO 2020/08 What was accomplished under these goals? Conduct field-based research and on-farm demonstrations in a partnership between stakeholders and scientists for better understanding of the influence of rotational and intercropping on greenhouse gas emission, crop yield, forage nutritive value, and soil health in integrated transitioning forage systems. At MTSU, we have completed collecting forage biomass, nutritive data, and botanical composition data. Our team is currently synthesizing all field data and budgetary records and preparing manuscripts that will be submitted to scientific journals. Dr. Nave's group at MTREC has continued for another year of data collection. Main accomplishments consisted of the following: 1) continued annual rotation

system as previously planned; 2) constructed establishment and maintenance budget skeletons on a treatment basis using existing budgets and previous work on organic fertilizer pricing; 3) produced herbarium specimens (deposited at Austin Peay) and weed presence data with a final weed survey, 4) comparison of the project to UT variety trials and published work on the same farm under comparable management conditions to develop a yield penalty for the organic harvest, and 5) plant alfalfa which succeeded in the bermudagrass-alfalfa plots. Soil health response to different forage species were investigated in Dr. Jagadamma's laboratory. Soil samples from 0 to 30 cm depth were collected twice a year to analyze soil health determining properties such as soil organic carbon, total nitrogen, mineral nitrogen, pH, and other soil nutrients. Results showed that perennial mixtures, especially the combination of warm-season grass and cool season legume, have the greatest potential to improve soil health in organic transitioning systems. Soil moisture, organic carbon, microbial biomass carbon, and mineral nitrogen were higher under bermudagrass + alfalfa treatment than under bermudagrass monocultures and other forage species. We also conducted a laboratory microcosm experiment to understand the climate resiliency of soils under organic management. Preliminary results show that microbial biomass carbon and soil respiration were greater under organic farming compared to conventional farming across temperature treatments. Quantify and characterize how transitioning into organic forage management practices can affect the water, greenhouse gas, and energy fluxes and dynamics in predominant forage production agroecosystems of the fescue belt region. Both eddy-covariance systems (one on a conventional forage ecosystem, another on a certified system) have been functioning properly and are continuously logging water, greenhouse gas, and energy fluxes data. We are in the process of performing data QA/QC procedures, including gap-filling data, partitioning the net ecosystem exchange into both gross primary production and soil respiration components to fully investigate the differences in ecosystem behaviors. Develop optimal management practices that optimize both agronomic/economic profitability and ecosystem function in transitioning forage production systems. Our preliminary results indicated that annual forage systems could provide the greatest yield but with very limited contribution to the overall soil carbon pool and extremely poor economic return, mainly due to the high seed cost (particularly certified seeds) and large labor input (tillage, planting, harvesting, etc.). Perennial systems, particularly perennial warm-season grass-legume bicultures indicated the optimal economic return, soil carbon enhancement, and biomass yield. Extra caution was needed on the legume species selection and how to maintain nutritive value during the end of the growing season. Develop an educational and outreach paradigm for efficient transfer of project findings to stakeholders and public individuals. Organize training and extension efforts on the farming strategies, certification processes, and economic decision-making while transitioning to organic forage production systems. The focus has transitioned to using research data to construct transition and maintenance budgets for organic forage production. In doing this, this information will be available to producers to help them better understand the risks, challenges, and costs of transitioning to organic forage production. At the same time, we are calculating the cost of production on a forage yield and nutritive basis which will provide a pure estimate of costs to forage and livestock production. We continue to work with individual producers who are establishing or reestablishing forages and how to reduce costs throughout the life of the forage stand.

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[↑ Return to Index](#)

Introducing Organic to Producers of Grain-only and Pasture-grain Wheat Cropping Systems of Northern Texas.

Accession No.	1013519
Project No.	TEX09702
Agency	NIFA TEX\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2017-51106-27002
Proposal No.	2017-03389
Start Date	01 SEP 2017
Term Date	31 AUG 2020
Grant Amount	\$499,802
Grant Year	2017
Investigator(s)	Adams, C.; Pinchak, WI, E.; Park, SE, .; Somenahally, AN, C.; Bell, JO, .; Kimura, EM, .
Performing Institution	TEXAS A&M UNIVERSITY, 750 AGRONOMY RD STE 2701, COLLEGE STATION, TEXAS 77843-0001

NON-TECHNICAL SUMMARY

In the Southern Great Plains region of northern Texas, wheat and beef cattle agriculture are closely associated in ways that are uncommon elsewhere in the U.S. Much of the wheat that is planted is grown specifically for grain, which goes into both food and feed markets. But more than 50% of wheat acreage in the region is utilized in "pasture-grain" wheat cropping systems that are managed to support livestock grazing and to produce a grain crop. These wheat-based systems have regional and national importance, as many beef cattle are shipped to the region for winter grazing and grain is shipped near and far. The systems are characterized by being expansive and relatively low yielding, in part due to historical agricultural management practices, such as monocropping and maintenance of fallow in off-season periods that take a significant toll on productivity and economic viability. In our communications with regional agricultural producers, they often express interest in finding new markets to enter that would improve their operations economically. When organic agriculture is discussed, most producers lack knowledge on organic but are interested in learning more. Organic agriculture is nearly absent in the Southern Great Plains region of Texas. In investigating specific barriers to organic adoption, we found a variety of issues that we could address to give producers the tools to make the transition to organic. On the buyers end, we have learned that companies that source organic wheat and beef from Texas experience supply shortages. All of this stakeholder information showed us the importance of developing an interdisciplinary project devoted to organic agriculture transition in this region and we have used stakeholder input in tailoring and planning the project to meet their needs. Our long-term goal in this project is to expand production of organic wheat and beef production in this region and in doing so to give producers more market options, improve rural economic prosperity, improve environmental stewardship, and expand organic supplies of wheat and beef. In our research, we will directly compare conventional grain-only and grazing-grain wheat systems, with all the most common regional management practices in place, to transitional organic systems that will be managed using regionally adapted cover crops, regionally available organic fertilizer sources, and crop rotation. The experiment will occur at a large field scale (100 acres), providing results that are directly transferrable to regional stakeholders by characterizing the transition to organic with animal impacts on the systems. We will quantify system management impacts on crop and animal performance; soil microbial, nutrient, greenhouse gas emission, and moisture dynamics; and economic outcomes. We will connect our results between disciplines in understanding how individual processes affect whole system function during the transition. An intensive extension outreach effort will

be used to take the research results to stakeholders across our 44,000 square mile project area and to provide basic and in-depth education on organic agriculture. Impacts on higher education will also be made, as we will prepare curriculum for a course section on the basic principles of organic agriculture that will be delivered and taught to cooperating agriculture instructors in two regional institutes of higher education. To summarize simply, we expect these project activities to open doors that were otherwise unavailable and to improve conditions for the various stakeholders of this project.

OBJECTIVES

Our long-term goal in this project is to expand production of organic wheat and beef production in the Southern Great Plains region of Texas and in doing so to give producers more market options, improve rural economic prosperity, improve environmental stewardship, and expand organic supplies of wheat and beef. As faculty of the flagship land grant institution for the state, the Texas A&M University System, who are based in the Southern Plains region, our team is ideally suited to conduct this project. In our research, we propose to utilize a systems approach to directly compare conventional grain-only and grazing-grain wheat systems, with all of the most common regional management practices in place, to transitional organic systems that will be managed using regionally adapted cover crops, regionally available organic fertilizer sources, and crop rotation. The experiment will occur at a large field scale (100 acres), which is the only way to provide results that are directly transferrable to regional stakeholders, truly characterizing the transition to organic with animal impacts on the systems. We will quantify system management impacts on crop and animal performance; soil microbial, nutrient, greenhouse gas emission, and moisture dynamics; and economic outcomes. These measurements will allow us to quantify ecosystem services and biological diversity, and to assess the sustainability of the systems. We will connect our results between disciplines in understanding how individual processes affect whole system function during the transition. An intensive extension outreach effort will be employed to take the research results to stakeholders across our 44,000 square mile project area and to provide basic and in-depth education on organic agriculture. Impacts on higher education will also be made, as we will prepare curriculum for a course section on the basic principles of organic agriculture that will be delivered and taught to agriculture instructors in two regional institutes of higher education. The specific objectives for the project are listed below, grouped by research, extension, and education activities.

Research Our research efforts are focused on developing and validating management practices for organic grain-only and pasture-grain wheat cropping systems for this region and understanding some of the basic mechanics and economics of the transition from conventional management. We will be utilizing a systems research approach that directly compares conventional systems, with all of the most common regional management practices in place, to transitional organic systems that will be managed using regionally adapted cover crops, regionally available organic fertilizer sources, and crop rotation. The experiment will occur at a large field scale (~100 acres) and with a design that will make the results directly transferrable and useful to regional stakeholders. The proposed measurements will allow us to quantify ecosystem services and biological diversity, and to assess the sustainability of the systems. Our objectives are: To assess a cover crop mixture for provision of N and other ecosystem services and to reformulate it as needed; To quantify cash crop productivity and quality in organic transition; To quantify grazing cattle performance in a pasture-grain wheat cropping system organic transition; To assess soil microbial abundance, diversity, and nutrient cycling; greenhouse gas emissions; and moisture dynamics in organic transition; To perform preliminary economic analysis of the transition to organic based on regional factors and a final analysis integrating outcomes of our research.

Extension Our extension outreach efforts will reach across a broad portion of northern Texas, an area of about 44,000 square miles. The area covers the entire Texas panhandle, reaches southeast almost to Dallas, and almost as far south as Abilene. Our objectives are: To introduce the project to regional wheat and beef producers and make them aware of the scope of our efforts; To disseminate the results of our research to producers and provide basic education on organic agriculture; To conduct workshops providing in-depth education to producers on transition into organic agriculture; To invite regional wheat and beef producers to attend a field day at the West Walker ranch.

Education Many of our extension activities are also education activities, but we will additionally be making an impact in higher education. Vernon College (Vernon and Wichita Falls, TX) and West Texas A&M University (Canyon, TX) are institutions of higher education that educate members of the regional agricultural workforce. We will be working with cooperating instructors of agriculture to educate students on organic agriculture. Our objectives are: To prepare curriculum for a course section on the basic principles of organic agriculture To educate agriculture instructors at regional institutions of higher education on this curriculum

APPROACH

As an integrated project, there are Research, Extension, and Education components, the approaches to which are described in three sections below. **Research** A large-scale field study (102 acres) will facilitate investigation of

the transition to organic management in both pasture-grain and grain-only wheat cropping systems. The study site is 10 miles south of Vernon, TX at a property maintained by the Texas A&M AgriLife Research and Extension Center at Vernon. We will divide the entire 102 acre land area into eight 12.75 acre plots by portable fences and randomly assign pasture-grain treatments within blocks. A smaller ¼ acre area will be nested within each pasture-grain plot and fenced off for placement of a complementary grain-only treatment plot. Transitional organic systems will be compared to systems with conventional management. The defining characteristics of conventional management for this region include: monocropping (continuous) wheat; herbicidal and tillage-based maintenance of a summer fallow period; and use of agricultural chemicals for fertility and disease management. The organic cropping systems will be operated with certifiable practices that are tailored for this agricultural ecoregion. The defining characteristics of this management style will include: crop rotation of wheat with canola, summer cover cropping, and use of locally sourced composted manure to add fertility and enhance soil health. Within these systems, we will focus on: 1) optimizing a cover crop mixture year-by-year to provide ecosystem services, including N fixation, soil carbon deposition, soil cover and stability, nutrient sequestration, and reduced weed pressure; 2) characterizing crop responses to management, including nutrient uptake, forage and grain productivity, and forage quality; 3) the performance (weight gain) of stocker cattle in the dual-purpose systems; 4) soil nutrient, microbial, and greenhouse gas emission responses to management; and 5) an economic characterization and comparison among systems. We will collaborate to connect the results among disciplines, generating mechanistic understanding of the systems and information that is directly applicable to stakeholders and of scientific value. Extension All of our extension efforts will be focused on informing stakeholders about this project expanding producer knowledge of all facets of organic agriculture so enable decision making, and connecting organic producer and buyers. Our outreach effort will occur throughout the three-year project period at extension events at the county and regional levels, through extension publications, and media outlets. Extension events include county-level field days, county-level winter workshops, the Red River Crops Conference (RRCC), and the Cattle Trail Cattle Conferences (CTCC). Both conferences are joint efforts between Texas A&M AgriLife Extension and Oklahoma State University Cooperative Extension Services, where more than 500 producers attend to learn about trending topics in crop and animal agricultural production. We will also hold a field day at our field site in the final year of the project, allowing producers to view the research and hear results. The education on organic agriculture that will occur at these events will include informing producers about USDA requirements of organic operations; organic practices for managing fertility, pests, disease, and weeds; government resources available to assist organic farmers; and other topics. The media outlets we will utilize for dissemination of information will include: 'AgriLife Today' (<http://today.agrilife.org/category/farm-ranch/>), a popular press periodical that reaches approximately 700 subscribers; the Rolling Plains Agronomy Blog (<http://agrilife.org/txrollingplainsagronomy/>); and the Amarillo Agronomy website (<http://amarillo.tamu.edu/amarillo-center-programs/agronomy/>). Two workshops on organic agriculture will be held at the Texas A&M AgriLife Research and Extension Centers at Vernon and Amarillo in the second year of the project. We expect these to be transformative events at which producers can greatly increase their knowledge of organic agriculture. We will educate producers on the USDA requirements for organic operations and on organic practices for managing fertility, pests, disease, and weeds. We will familiarize and connect producers with regional buyers for organic wheat and beef products. We will educate producers on government resources that are available to them to transition their operations into organic, including the cost-share program for organic certification through the FSA. At our extension events, we will distribute questionnaires to see what producers learned, determine the likelihood that they will take action based on what was presented, and see if they have unanswered questions. Talks at subsequent meetings and our publications and media posts will be guided by the feedback. Extension publications on organic management of wheat and beef cattle will be generated and posted online. Education We will prepare curriculum for a course section on the basic principles of organic agriculture and deliver it to cooperating instructors of agriculture at Vernon College and West Texas A&M University. These institutions educate much of the agricultural workforce in this region. The following topics will be summarized in this curriculum section: a brief history of USDA organic certification of agricultural products; current figures and future projections of US organic production and consumption; and basic characteristics of organic crop and animal management in systems common in Texas. ****Progress**** 09/01/17 to 08/31/22 ****Outputs**** Target Audience: Winter wheat stakeholders in the Southern Great Plains. Our intent was to provide objective science-based results of the relevant soil to sale opportunities and challenges of transitioning from conventional to organic hard red winter wheat production. Through participation and presentation of results at local, regional and national organic cropping meetings we were able to learn and communicate with industry stakeholders from farmers to bakers. This led to refining our organic research and extension approaches throughout the study period. **Changes/Problems:** Overarching problems/challenges throughout the study period was the very high cost of sourcing and applying composted manure, generation of adequate cash flow in the fallow periods in the organic system and still building cover crop derived soil nitrogen. In years with organic wheat grain production, grain protein levels were below minimum standards for food grade organic wheat premiums. Recently, we have identified a closer manure source and a local contractor that can manage and apply composted manure. Our

next generation organic winter wheat research will include a more diverse subset of small plots to test various sources on organic fertilizer application rates. Grazing will be included during cover crop rotation periods to enhance nitrogen retention on site and improve soil nitrogen availability. Drought frequency is increasing, and we will explore management approaches to mitigate those impacts. What opportunities for training and professional development has the project provided? A PhD candidate mentored by Dr. Adams successfully completed his Doctoral program and graduated in 2021. He conducted much of the research on the project. He has been closely mentored in the research process and in his professional development as a scientist. He is currently a Post- Doctoral Research Fellow in Pennsylvania. Other graduate students from Dr. Adams's lab have also been involved in project activities, one of whom graduated Fall 2020. An undergraduate research intern was hired from Vernon College to assist in project activities; she was mentored in the research process, then was hired on as a full-time research technician following her graduation. How have the results been disseminated to communities of interest? To date, three refereed journal articles have been published from 2021-2022. Another is in review and two are in preparation. One extension bulletin is published and another is under internal review for submission in 2023. Eight conference presentations at National and Regional venues. Three popular press articles on the project. Nine audio/video products sharing outcomes from this project. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

****Impacts**** What was accomplished under these goals? Research Goals 1 to 3 were completed over the study period. We partially completed measurements for Goal 4 and have published those relative to nutrient cycling and soil moisture dynamics. We are currently analyzing greenhouse gas emissions data for publication in 2023. Unfortunately, post-sample collection problems precluded completing the soil microbiome component of Goal 4. Extension Goals 1 to 4 were variably completed. Goals 1 and 2 were achieved through extension programs, development of organic sections on webpages, and popular press articles. COVID dramatically impacted our capacity to hold workshops (Goal 3) and none were held as a result. Severe drought during the 2021-2022 winter wheat production cycle led to crop failures at the research location and the field day was canceled. We are planting wheat again now following recent rainfall and look to hold a field day in 2023. Education Goal 1 to develop a curriculum for a course section on principles of organic agriculture was accomplished. The curriculum is under review and will be modified as need before sharing it with regional universities and colleges in 2023. Educating agriculture instructors is planned for summer 2023.

****Publications**** - Type: Journal Articles Status: Published Year Published: 2022 Citation: MacMillan, J., Adams, C., Hinson, P., DeLaune, P., Rajan, N., Trostle, C. 2022. Biological nitrogen fixation of cool-season legumes in agronomic systems of the Southern Great Plains. *Agrosystems, Geosciences and Environment* 5:e20244. - Type: Journal Articles Status: Published Year Published: 2022 Citation: Hinson, P., Adams, C., Pinchak, B., Jones, D., Rajan, N., Somenahally, A., Kimura, E. 2022. Organic transition in dual-purpose wheat systems: Agronomic performance and soil nitrogen dynamics. *Agronomy Journal* 114:2484-2500. - Type: Journal Articles Status: Under Review Year Published: 2022 Citation: Hinson, P., Pinchak, B., Adams, C., Jones, D., Rajan, N., Kimura, E., Somenahally, A. 2022. Organic transition in dual-purpose wheat systems: Forage production, nutritive value, and cattle gains. *Agronomy Journal* - Type: Other Status: Published Year Published: 2021 Citation: MacMillan, J., Hinson, P., Adams, C., Kimura, E., Trostle, C. 2021. Nitrogen fixation by cool-season legumes in agronomic systems. Texas A&M AgriLife Extension Service. SCSC-PU-230 - Type: Other Status: Under Review Year Published: 2022 Citation: Adams, C., Hinson, P., Pinchak, B., Jones, D., MacMillan, J., Abello, F., Bell, J., Kimura, E. 2022. Organic transition in dual-purpose wheat systems. Texas A&M AgriLife Extension Service. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Abello, F., Fan, Y., Adams, C., Pinchak, B., Hinson, P. 2022. Economic analysis on organic transition of a dual-purpose wheat system in the Southern Great Plains. Southern Agricultural Economic Association Annual Meeting, Feb. 12-15, New Orleans, LA. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Hinson, P., Pinchak, B., Adams, C., Rajan, N., Somenahally, A., Kimura, E. 2021. Forage productivity and nutritive value of a transitional organic wheat system in the Southern Great Plains. ASA/CSSA/SSSA Annual Meeting, Nov. 7-10, Salt Lake City, UT - Type: Other Status: Other Year Published: 2023 Citation: Adams, C., Hinson, P., Pinchak, B., Jones, D., MacMillan, J., Abello, F., Bell, J., Kimura, E. 2022. Organic transition in dual-purpose wheat systems. Texas A&M AgriLife Extension Service. In Preparation.

****Progress**** 09/01/20 to 08/31/21 ****Outputs**** Target Audience: We reached agricultural producers, researchers, and the general public during this reporting period. Changes/Problems: Nothing Reported

What opportunities for training and professional development has the project provided? A PhD candidate advised by Dr. Adams has been conducting much of the research on the project. He has been closely mentored in the research process and in his professional development as a scientist. Other graduate students from Dr. Adams's lab have also been involved in project activities, one of whom graduated Fall 2020. An undergraduate research intern was hired from Vernon College to assist in project activities; she was mentored in the research process, then was hired on as a full-time research technician following her graduation. How have the results been disseminated to communities of interest? Through PI websites, Extension meetings, scientific conferences, and personal contacts, as described in the accomplishments section. Scientific conferences included the annual meeting of the ASA/CSSA/SSSA and the Texas Plant Protection Conference. We also submitted manuscripts to a journal and

Texas A&M AgriLife Extension for peer-review of project results as a journal article and Extension publication. What do you plan to do during the next reporting period to accomplish the goals? August to October 2021 - Complete development of an organic curriculum section and deliver it to Vernon College, West Texas A&M University, and Amarillo College. August to September 2021 - Complete analysis of plant and soil fertility data. August to October 2021 - Process the greenhouse gas samples, compile and analyze the data. August to October 2021 - Process the soil microbiology samples, compile and analyze the data. August to December 2021 - Perform system economic analysis. August 2021 to August 2022 - Write and publish scientific manuscripts and extension publications. April 2022 - Field Day at the West Walker Ranch, our field site.

****Impacts**** What was accomplished under these goals? During this reporting period, we worked on Research Objectives 1, 2, 3, 4, and 5 and Extension Objective 2, and Education Objectives 1 and 2. Research Objectives: We successfully managed our experimental field site, comparing conventional and transitional organic winter wheat cropping systems. A cover crop was established in the organic plots for summer 2020, which was tilled under as green manure in the fall, and both the conventional and organic systems were planted to wheat for the 2020/2021 winter season. Limited forage production due to low rainfall early in the winter season prevented turnout of cows to the wheat. Data was collected on cover crop production, wheat production and physiological traits, wheat forage production and nutritive values, crop nitrogen and phosphorus nutrition, soil fertility, soil microbiology, and soil greenhouse gas emissions, according to plans. Despite not being able to graze wheat forage, the forage production and nutritive value information will enable us to make estimates of potential cattle performance in the systems. All the data from this reporting cycle is currently being compiled and analyzed with the data collected from all years of the experiment. We also organized and compiled field management information for the entire project period. We are currently drafting publications that will present the core results of this project. Final economic analysis of the project results is beginning now. We have one peer-reviewed publication in review that presents results on biological nitrogen fixation from the legume-based hay crop in the organic system. We also presented project results at scientific conferences. Extension Objectives: Drs. Kimura, Bell, and Adams maintain organic sections within their websites, which are updated with information and resources from this project. We published our Texas A&M AgriLife Organic Workshop as a permanent online resource during the last reporting period. During this reporting period, project PIs promoted that resource online and in person, plus fielded questions about it from regional producers and Extension agents. Covid-19 precautions prevented most in-person Extension events during this reporting period, though Drs. Kimura and Bell discussed this project in county-level wheat Extension meetings, where possible. We developed an Extension publication on biological nitrogen fixation in cool-season legumes based on the peer-reviewed publication mentioned above, which is also currently in peer review. Education Objectives: Drs. Kimura, Bell, and Adams largely completed development of a curriculum section on organic agriculture during the reporting period. We included results and take-home messages from this research project in the curriculum. The curriculum will be completed early in the next project period, then delivered to instructors of agriculture at Vernon College, West Texas A&M University, and Amarillo College.

****Publications**** - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Hinson, P., Adams, C., Pinchak, B., Somenahally, A. 2020. Organic transition in dual-purpose wheat systems of the Southern Great Plains: Data and experience after two years of management. ASA/CSSA/SSSA Annual Meeting, Nov. 8-11, Virtual. - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: MacMillan, J., Adams, C., Hinson, P., DeLaune, P. 2020. Quantifying biological nitrogen fixation of cool-season legumes in three systems in the U.S. Southern Great Plains. 32nd Annual Texas Plant Protection Conference, Dec. 8-10, Virtual. - Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: MacMillan, J., Adams, C., Hinson, P., DeLaune, P. 2020. Quantifying biological nitrogen fixation in winter legumes in the Southern Great Plains. ASA/CSSA/SSSA Annual Meeting, Nov. 8-11, Virtual.

PROGRESS

2017/09 TO 2018/08 Target Audience: We reached agricultural producers, researchers, policy makers, and the general public through publication of a popular press article that introduced and educated on the project ("AgriLife Research project to examine, educate on organic wheat systems," October 11, 2017, "AgriLife Today"). We reached regional agricultural producers through a presentation detailing the project at the Rolling Plains Winter Crops Field Day, held at the Chillicothe Research Station near Chillicothe, TX on August 30, 2017. We estimate that 95 people were in attendance. We reached leaders in the Texas wheat industry and fellow researchers through a presentation that described the project at a regional scientific/research-user meeting ("Introducing organic to producers of grain-only and dual-purpose wheat cropping systems of the Southern Great Plains," Small Grains Workers Meeting, College Station, TX, August 1-2, 2018). Changes/Problems: The project was initiated and funds were received in fall 2017, at the beginning of the winter wheat growing season. For this reason, our first major stated research objective was to establish and assess a cover crop in the transitional organic plots in summer 2018. Severe drought conditions prevented even planting the cover crop, which delayed

the onset of the research, but project funds still had to be expended to manage the land. The unfortunate weather conditions will allow us two, rather than three, seasons to evaluate and reformulate the cover crop mixture for use in regional organic winter cropping systems. What opportunities for training and professional development has the project provided? A graduate student was recruited to work on the project with Dr. Adams in fulfillment of the requirements of a PhD. He began his program in January 2018. He has taken one semester of relevant coursework, been mentored in development of a research (dissertation) proposal, been taught and studied about organic and sustainable agriculture, and been mentored in research approaches. A postdoctoral research associate and undergraduate research assistant working in Dr. Adams's lab have participated in project preparation and increased their knowledge of organic and sustainable agriculture and research approaches. How have the results been disseminated to communities of interest? We introduced the project and made people aware of the full scope of our planned efforts through a popular press article, a field day presentation, and a presentation at a regional scientific/research-user meeting, as described above. At this early stage of the project, no project results are ready for dissemination to communities of interest. What do you plan to do during the next reporting period to accomplish the goals? During the next reporting period, complete winter (wheat) and summer (cover crop or fallow) cropping seasons will have passed. We hope to have better environmental conditions that will facilitate successful crops and field data collection. We will establish transitional organic and conventional wheat systems for the 2018/2019 winter season; quantify in-season wheat forage productivity; compare grazing cattle weight gains between systems; gather initial data on soil biological processes, nutrient cycling, and carbon; and quantify wheat grain yield. We will establish a mixed species cover crop in the transitional organic systems, measure growth of its components, estimate its provision of nitrogen, and use the data to make prudent changes to its composition for future years. The ongoing work of the project will be discussed in field days and other extension events.

2019/09 TO 2020/08 Target Audience: We reached agricultural producers, researchers, organic industry representatives, government employees, and the general public during this reporting period. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? A graduate student (PhD candidate) advised by Dr. Adams has been conducting much of the research on the project. He has been closely mentored in the research process and in his professional development as a scientist. Due to their interest in this project, another doctoral student and a master's student in Dr. Adams's lab have also contributed broadly to project activities. An undergraduate research assistant was hired to assist in the activities of this project and has been mentored in the research process. How have the results been disseminated to communities of interest? The Texas A&M AgriLife Organic Workshop (25 April 2020), which is published online, provided us with a venue to disseminate the results of our research project and to educate agricultural producers on other relevant topics. Two popular press articles were published in AgriLife Today to promote the workshop and make it accessible to producers and the general public. Dr. Adams was also invited and presented on the project at the 2020 Small Grains Workers meeting, an annual conference that brings together researchers and producer representatives who work on small grains in Texas. What do you plan to do during the next reporting period to accomplish the goals? Our ongoing field research will be continued during the next reporting period in fulfillment of Research Objectives 1 - 4. The 2020/2021 winter season will be the third season of our field experiment and both conventional and transitional organic systems will be managed in dual-purpose wheat, which will provide an excellent side-by-side comparison of the performance of the systems at the conclusion of the organic transition period. We will collect data on crop productivity, grazing cattle gains, crop nitrogen and phosphorus nutrition, soil fertility, and soil microbiology. As an exceptional item in Objective 4, data on greenhouse gas emissions will be collected during the third season to provide a comparison between conventional and transitional organic systems. In addition to the data collected from the field, management notes will be taken that will be used in economic analysis to fulfill Research Objective 5. Beginning in summer 2021, following collection of all data from the third field season, we will summarize and analyze the data from all seasons. Once complete, manuscripts will be prepared for submission to scientific journals. We will prepare one or more extension publications to educate regional agricultural producers on the organic transition process and to convey our research directly to them. We will fulfill Education Objectives 1 - 2. This will involve preparing curriculum for a course section on the basic principles of organic agriculture that will be delivered to two regional Colleges/Universities. We will educate cooperating instructors of agriculture on this curriculum, which they can insert into their existing courses to modernize and enhance the material they teach.

IMPACT

2017/09 TO 2018/08 What was accomplished under these goals? Extension Objective #1 was accomplished: To introduce the project to regional wheat and beef producers and make them aware of the scope of our efforts. This

was accomplished through a popular press article, a field day presentation, and a presentation at a regional scientific/research-user meeting, as described in the following paragraphs. We introduced and educated people on the project through a popular press article titled "AgriLife Research project to examine, educate on organic wheat systems" on October 11, 2017 in "AgriLife Today" (<https://today.agrilife.org/2017/10/11/agrilife-research-project-examine-educate-organic-wheat-systems/>). AgriLife Today reaches approximately 700 subscribers, including producers, researchers, policy makers, and news media. AgriLife Today articles are frequently reprinted in other news outlets, allowing a broader reach to the general public. We received direct contact and feedback from prospective organic wheat producers, organic industry representatives, and fellow researchers in response to the article. We introduced the project directly to regional agricultural producers at the Rolling Plains Winter Crops Field Day, held at the Chillicothe Research Station near Chillicothe, TX on August 30, 2017. The entire scope of the project, including planned research, extension, and education activities, were detailed. We estimate that approximately 95 people, mostly producers, were in attendance, representing the western half of our project area. We received questions, comments, and interest from producers. Dr. Adams gave a presentation on the project titled "Introducing organic to producers of grain-only and dual-purpose wheat cropping systems of the Southern Great Plains," at the Small Grains Workers Meeting, held in College Station, TX on August 1-2, 2018. This meeting is organized as a venue for researchers working on small grains, including wheat, to present and discuss their research to leaders in the Texas wheat industry and fellow researchers. The Executive Vice President of the Texas Wheat Producers Board was in attendance; he asked questions following the presentation and expressed the value he saw in the project for Texas wheat. This presentation made wheat researchers within the Texas A&M System aware of our efforts, which we hope will facilitate synergies in the project. We received tips and suggestions to make connections with organic industry players that we were previously unaware of. We prepared the field site and readied infrastructure and supplies, so our research can be conducted. We prepared every necessary thing for planting and assessing a summer cover crop in the organic plots. Organic wheat producers in this region will rely on cover crops that include legumes to provide nitrogen for their wheat, suppress weeds, stabilize soil and nutrients, and render other ecosystem services. In general, a summer cover crop is viable in this region. This year, we had severe drought conditions regionally, but especially at the field site where no substantial rainfall came during the summer, that prevented even planting the cover crop. We experienced a real-life situation that will negatively affect regional organic wheat producers. This will be part of the narrative as we communicate with producers about the project. ****PUBLICATIONS (not previously reported):**** 2017/09 TO 2018/08 1. Type: Other Status: Published Year Published: 2017 Citation: Ledbetter, K. 2017. AgriLife project to examine, educate on organic wheat systems. AgriLife Today, Oct. 11. 2. Type: Conference Papers and Presentations Status: Other Year Published: 2018 Citation: Adams, C., B. Pinchak, S. Park, A. Somenahally, E. Kimura, J. Bell. 2018. Introducing organic to producers of grain-only and dual-purpose wheat cropping systems of the Southern Great Plains of Texas. Small Grains Workers Meeting, Texas A&M AgriLife, Aug. 1-2, College Station, TX. No 2018-19 report as of Dec 19, 2019.

2019/09 TO 2020/08 What was accomplished under these goals? During this reporting period, we addressed Research Objectives 1, 2, 3, 4, and 5 and Extension Objectives 2 and 3. We successfully managed our experimental field site, comparing conventional and transitional organic winter cropping systems. High-quality data was collected on crop and cover crop productivity, crop nitrogen and phosphorus nutrition, soil fertility, and soil microbiology according to plans. This data will be compiled and analyzed with the data collected from all years of the experiment. According to plan, the conventional system was planted to wheat and the transitional organic system was rotated to a legume-based hay crop in the 2019/2020 winter season. Limited forage production due to low rainfall early in the 2019 winter season prevented turnout of cows to the conventional wheat, thus the crop was not "dual-purpose" in this season. Rainfall picked up in the mid-to-late season, improving the growth of both conventional and organic crops. Under these conditions, growth of the legume-based hay crop was excellent, nodules were present on legume roots, and we are testing for rates of biological nitrogen fixation in the system. In summer 2020, the conventional system was fallow and the transitional organic system was planted with a forage cowpea cover crop, which will be tilled under as green manure in the fall. Rainfall has been sufficient this year to allow excellent growth of the cover crop. Our hope is that the winter and summer legumes left a legacy of nitrogen in the soil to narrow the yield gap between conventional and transitional organic dual-purpose wheat crops in the 2020/2021 winter season. The bulk of Research Objective 5 (economics) will be addressed in the next project period, but we did gather data and recorded management information that will be used in economic analysis and we recruited a new economist during the reporting period to join the project to replace our original economist who moved on to other employment. We hosted the "Texas A&M AgriLife Organic Workshop" online in April 2020, completely fulfilling Extension Objective 3. The workshop also helped fulfill Extension Objective 2. The workshop was done virtually due to restrictions from COVID-19, rather than in-person in Amarillo and Vernon, TX. The purpose of the workshop was to provide information to regional agricultural producers on how to successfully transition into organic production and manage an organic operation. Experts in the region were recruited to speak on the following topics: organic certification, crop

insurance and Farm Service Agency (FSA) programs for organic production, marketing of organic products, considerations in becoming an organic wheat farmer, integrating goats into organic systems, integrated pest management (mites, nematodes, and Bt resistance), and an update on the progress of our transitional organic dual-purpose wheat systems research. **PUBLICATIONS (not previously reported):** 2019/09 TO 2020/08 1. Type: Other Status: Published Year Published: 2020 Citation: Ledbetter, K., Kimura, E., Bell, J., Adams, C. 2020. Online Texas A&M AgriLife Organic Workshop now available. AgriLife Today, 27 April. 2. Type: Other Status: Published Year Published: 2020 Citation: Ledbetter, K., Bell, J., Kimura, E., Adams, C. 2020. Texas A&M AgriLife to offer online Organic Workshop for High Plains, Rolling Plains. AgriLife Today, 26 February. 3. Type: Conference Papers and Presentations Status: Published Year Published: 2020 Citation: Adams, C., Hinson, P., Pinchak, B., Somenahally, A. 2020. Organic transition in North Texas wheat systems: Year two research progress. Virtual Small Grains Workers Meeting, Aug. 4, Administered Online from College Station, TX. ' ** **

[↑ Return to Index](#)

An Ecological Approach to Disease Risk Management on Organic Poultry Farms.

Accession No.	1013573
Project No.	WNP06700
Agency	NIFA WN.P\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2017-51106-27026
Proposal No.	2017-03409
Start Date	01 SEP 2017
Term Date	31 AUG 2020
Grant Amount	\$458,145
Grant Year	2017
Investigator(s)	Owen, J.; Snyder, WI, .; Crespo, RO, .
Performing Institution	WASHINGTON STATE UNIVERSITY, 240 FRENCH ADMINISTRATION BLDG, PULLMAN, WASHINGTON 99164-0001

NON-TECHNICAL SUMMARY

Organic poultry are free to roam in outdoor settings. This encourages normal foraging and integrates poultry with the soil, vegetation and wildlife that are natural parts of farm ecosystems. While bringing benefits for animal welfare and farm ecology, there are also risks. Outdoor poultry are exposed to parasites and pathogens in the soil (e.g. Coccidia and Salmonella), or vectored by wild birds (e.g., Avian influenza virus and ectoparasites). These infections endanger animal and human health. There have been very few holistic studies of factors that make organic poultry farms susceptible or resistant to parasite/pathogen invasion. Growers' inability to predict and manage these risks forms a major barrier to organic transition. Working on farms with free-range and pastured poultry, we will fill these knowledge gaps by: (1) Measuring frequencies of poultry contact with wild birds and soil; (2) Surveying pathogen and parasite communities within on-farm wild bird populations, while characterizing transmission routes between wild and domesticated birds; and (3) Characterizing properties of soil that affect persistence of fecal-borne poultry parasites and pathogens. Each research objective leads directly to a specific outreach product, providing poultry producers with practical ways to reduce the risk of harboring parasites and pathogens on their farms. We address USDA-ORG priorities by (1) improving methods to describe and optimize environmental services in organic animal production while (2) reducing barriers to organic transition.

OBJECTIVES

The major goals of this project are to determine (I) the impact of wild bird species on the introduction and/or maintenance of poultry parasites, and (II) the effect of soil properties (biotic and abiotic) on the persistence of fecal-borne poultry parasites in farming systems that allow chickens to contact the ground and wildlife. The purpose of this work is to provide evidence-based guidance for improving biosecurity on organic poultry farms that are encouraged to place chickens on the ground outdoors. OBJECTIVES Objective 1: Characterize farm landscapes using GIS-based tools, and measure frequency/duration of contact between (i) poultry and wild birds and (ii) poultry and soil. Objective 2: Determine on-farm wild bird diversity, while measuring parasites and pathogens in both wild birds and chickens. Objective 3: Characterize on-farm soil properties and coprophagous invertebrates, followed by determination of soil factors that degrade feces-borne infectious organisms. Objective

4: Use data collected from objectives 1-3 to develop a risk model for potential infectious diseases in poultry systems that utilize outdoor access for birds.

APPROACH

Determination of wild bird community To characterize the communities of wild birds found on poultry farms, we will use visual observations (point counts). For each census a survey team (one Ph.D. student and one undergraduate researcher) will observe birds at 4 locations on a farm, twice in a day (morning and mid-day). At each selected location, one observer will identify and count birds within a 50-meter radius of the location over an 8-minute period. The second observer will identify and count birds beyond 50 meters using binoculars. The selected locations will include (i) occupied pastures/pens and (ii) farm infrastructure (e.g. barns), with adjustments made for different farm types and layouts. In addition, wild birds will be captured using mist nets and potter traps. Measurement of poultry contact with wild birds and soil Contact between wild birds and poultry, or poultry and the soil will be measured using visual observations of birds. This will involve observing flight-paths that carry wild birds over poultry such that feces from the wild birds would land in the foraging area of chickens. These "fly-overs" will be counted over set time-periods in the morning and evening. In addition, the contact of wild birds with infrastructure and feed will be quantified (e.g. # of birds contacting location X over 10 minutes). Poultry will be observed to determine the foraging patterns of flocks, and farmers will be interviewed to determine larger-scale management of flock locations (e.g. pasture rotation). Landscape data We will collect Geographical Information Systems (GIS) data at two scales. At broad scales, USDA-NASS crop maps (<http://www.nass.usda.gov/research/Cropland/SARS1a.htm>), available for free, can be used to identify the nature and extent of habitats surrounding each farm. However, these data are too coarse to reliably reveal the finer-scale hedgerows, outbuildings, small ponds, etc., that we know will also strongly impact bird populations. Therefore, the coarse USDA data will be supplemented with finer-scale GIS data at 30m or lower resolution. Data at this scale are often available from county agencies, or, in some cases, through regional Nature Conservancy offices. These GIS data will allow us to search for correlations between the densities of particular wild bird species (and/or wild-bird biodiversity) and small- and large-scale landscape features. To determine the scale over which landscape features impact wild bird populations, we will consider increasingly-broad concentric rings around each of the study sites looking for statistical consistency of landscape effects across ranges of distances. A consistent challenge with bird surveys of this type is that the failure to record a particular bird species during a farm visit reflects either (1) the bird truly is absent, or (2) the bird is present but was not seen that day. We will use "occupancy modeling" to estimate and account for these sampling errors; this is made possible by our repeated re-surveying of wild birds at our study sites several times per year over each year of the study. Parasite identification Parasites and pathogens will be identified in tracheal swabs, cloacal swabs, and fecal and blood samples collected from both poultry and wild birds on each farm. Samples will be sent to the Washington Animal Disease Diagnostic Laboratory (WADDL), located at Washington State University. This diagnostic laboratory will screen and identify enteric parasites (e.g. helminths, Coccidia, Salmonella and Campylobacter). Blood and swabs will be screened for viral pathogens (e.g. Avian Influenza and Marek's Disease virus). The diagnostic lab uses standard methods, such as microscope identification, bacteria culture and PCR. Soil characterization Soils will be sampled from the surface to a 10-cm depth. All samples will be a composite of 10 subsamples taken from within each pasture (or yard) at locations with high poultry activity or low poultry activity respectively (20 samples total). Spatial separation of the subsamples will be based on the size of the yard or pasture. The sampling locations will also be used as sites for pitfall traps and degradation studies are completed (see below). Samples will be shipped for chemical and physical analyses to Soil test Farm Consultants (www.soiltestlab.com). Potentially mineralizable nitrogen, microbial biomass, and C:N ratio will be determined. We will measure biodiversity among soil microbes, to determine whether this impacts the parasite/pathogen degradation in farms' soils. Our approach will be to sequence DNA in our soil samples using a metagenomic approach, which allows determination of both taxa and their functional genetic diversity. Parasite persistence test To determine the duration of time that parasites/pathogens survive in soil, we will conduct an experimental test of survival times of two parasites important to poultry health- Campylobacter and Eimeria. Soil samples will be collected from areas with high and low foraging activity on each farm. Samples will be pooled for each type of foraging area. We will collect feces from pathogen-free poultry (see below) and add fixed concentrations of Campylobacter bacteria and Coccidia oocysts (Eimeria sp.) to the feces. The Campylobacter will be obtained from a microbiology supplier (Microbiologics) and will be added to the feces to match a concentration reported for poultry feces (7 log CFU/ml). Coccidia oocysts (Eimeria sp.) will be obtained from Merck Animal Health as a suspension of attenuated, live vaccine (Coccivac-D), and added to the feces at a concentration of 20×10^3 oocysts/gram, to match a concentration shed from chickens. Replicates of inoculated soil samples will be held for 8 weeks and subsampled weekly to test for infectivity. Infectivity of pathogens will be tested by allowing pathogen-free chicks to contact the soil. Chicks will be euthanized and screened for infection 1-week after contact with the soil. Infection risk modeling To assess risks posed by parasites and pathogens carried by birds on farms, we will develop statistical

and spatial models that characterize the potential input of infectious organisms into (i) poultry on the farm and (ii) the human food supply. We are not measuring these transmission events directly. Instead, we are measuring properties of the birds and the soil, which serve as the reservoirs for these parasites and pathogens. These properties include bird species, abundances, spatial locations, frequency of contact with chickens, types of contact with the farming landscape, soil composition and weather. We will apply a Bayesian network approach to model the landscape and farming factors that influence the presence/absence of each infectious organism. In addition, we will utilize those models to determine what factors influence the diversity of infectious organisms represented in the bird community. Finally, we will use a logistic regression approach with GIS data to evaluate and map the spatial relationships among landscape features and infection risks. Overall, risk will be represented as a relative level of exposure to infectious organisms at the levels of the flock and local human population. Efforts to disseminate information to stakeholders will include development of online instructive videos and development of infographics ("Intercept Infection Cards") that can be delivered to producers. These infographics will explain the impacts of infectious diseases on poultry and the risk factors on farms that contribute to these infections.

Progress 09/01/17 to 08/31/22 **Outputs** Target Audience: The target audience consisted of poultry farmers and producers, as well as poultry breeders. The efforts to reach the target audience included presentation of research seminars to peer scientists, as well as preparation and delivery of research reports to participating farmers. PI-Owen and graduate students presented research findings to farmers and producers at state and national poultry meetings. Research findings were also presented to avian disease researchers at Hy-Line International, which is a poultry breeding company that supplies some of the most commonly used breeds of chickens on poultry farms. These efforts directly communicated important research findings to stakeholders at the production level and the research level. For participating farmers, we reported summary statistics on the parasites and pathogens found on each farm. In addition, we described the basic biology and associated health risks (poultry or human) associated with the parasites detected. These reports provided cooperating farmers with essential information to use in developing mitigation strategies. Changes/Problems: Field work for this project was severely impaired by the COVID-19 epidemic. The project team was unable to visit field sites as planned due to a combination of farmer hesitancy, University policies, and COVID infections among team members. In the last two years of the study, these problems were complicated further by nationwide outbreaks of avian influenza. Without full access to field sites, we shifted our research questions to utilize samples that we had already collected. Our early data collections revealed diverse chicken breeds used on organic farms that are not observed in conventional poultry production. We were able to explore the immunological characteristics of these breeds using laboratory based assays. This information has provided insights into what breeds may be used to prevent infectious diseases on organic poultry farms. What opportunities for training and professional development has the project provided? This project involved training of 2 M.S. students and one Ph.D. student. How have the results been disseminated to communities of interest? Data from this work has been disseminated through publication of manuscripts in peer reviewed journals, presentations to professional societies, and creation of extension publications. Over the lifetime of this project there have been 10 published manuscripts. At the time of the final REE report, there are 3 additional manuscripts in review and 3 more manuscripts in preparation. Presentations were made to poultry breeders and the Poultry Science Association. Finalized extension publications are in preparation with eOrganic (Oregon State University) to communicate results directly to stakeholders. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

Impacts What was accomplished under these goals? Project Impact: Organic production of chicken eggs and meat is a rapidly growing practice nationwide. Organic chicken egg sales more than doubled from 2014 (~166 million dozen sold) to 2017 (~399 million dozen sold). These sales reflect an increase in market value from ~\$419 million to ~\$887 million. Sales of chicken meat (broilers) from organic farms increased from ~\$372 million in 2014 to ~\$1.1 billion in 2017 (USDA National Agricultural Statistics Service). These statistics reveal that organic poultry production has grown to become a high value component of the poultry market. Importantly, many farmers are producing chickens under pastured and outdoor conditions, even though they lack USDA organic certification. A key motivation to produce chickens in these kinds of "open environments" is the appeal to consumers that believe it is healthier and more humane to raise chickens with access to foraging opportunities outdoors. An important barrier to the growth of the organic poultry market is the potential for parasites and pathogens to negatively affect production. Many parasites and pathogens that affect chickens are transmitted via feces or wildlife. These infectious organisms are controlled in conventional production systems by keeping chickens indoors where the farmer can limit chicken contact with the ground, remove feces, and block out wildlife. Under organic production, chickens can roam outdoors where they encounter soil, feces, insects, worms, and wild birds that are all potential sources of parasites and pathogens. This poses a serious risk to organic poultry production that has not been well characterized. As a result, it remains unclear what disease burdens may affect the organic poultry market and there is a lack of essential information to anticipate those risks and develop strategies to minimize disease impacts. The central objective of this research project has been to determine what parasites and pathogens may affect organic poultry production and limit the growth of the industry. The following summarizes activities and accomplishments within each of the project's main objectives over the last

reporting period: Objective 1: Characterize farm landscapes using GIS-based tools, and measure frequency/duration of contact between (i) poultry and wild birds and (ii) poultry and soil. We used statistical models to evaluate the wild bird species most observed contacting chickens in open environments. Of 91 wild bird species observed near poultry flocks, only 15 species exhibited regular contact with chickens. These data suggest it may be possible for farmers to develop targeted mitigation strategies to discourage wild bird contact with chickens, while also supporting bird diversity that is an important ecosystem service that many organic farmers seek to strengthen. These accomplishments represent a change in knowledge for farmers that previously lacked information about (i) the diversity and abundance of parasites that may affect flocks in open environments and (ii) the wild bird species that most frequently interact with chickens on the farm to create avenues for parasite introduction. With this change in knowledge, farmers and researchers will be better equipped to develop mitigation strategies to limit the impacts of these parasitic diseases and lower the barriers to growth of the organic poultry market. This information has been prepared in a manuscript that is currently under peer-review. This information is also being prepared for communication to stakeholders through extension bulletins created by eOrganic (Oregon State University). We determined that chicken contact with the soil was strongly influenced by farm management practices (e.g. flock rotation frequency), flock size, and chicken breed (meat versus layer). Importantly, we found that chicken-soil contact was highly varied among farms and that no single factor among the farms was a determinant of the duration of chicken-soil contact. This is important, because it indicates the reduction of parasite risk cannot be accomplished through modification of any single farming practice. Instead, management of parasitic disease on open environment poultry farms will have to be accomplished by consideration of the farming system. These results represent a change in knowledge for farmers that previously lacked information about the multiple ways that on-farm practices could affect risk of parasite exposure. This information has been prepared in a manuscript that is currently under peer-review. This information is also being prepared for communication to stakeholders through extension bulletins created by eOrganic (Oregon State University). Objective 2: Determine on-farm wild bird diversity, while measuring parasites and pathogens in both wild birds and chickens. Data collected for the project revealed 91 species of wild birds that live and forage on open environment poultry farms. Among poultry samples, 10 different groups of parasites and pathogens were detected. These data represent a change in knowledge for farmers that previously lacked information about the diversity of wild birds on the farm and the diversity of parasites infecting their flocks. This information will be essential to farmers that want to more closely monitor flock health and maximize wild bird diversity for their ecosystem services to other farm assets (e.g. removal of insect prey on crops). This information has been prepared in a manuscript that is currently under peer-review. This information is also being prepared for communication to stakeholders through extension bulletins created by eOrganic (Oregon State University). Objective 3: Characterize on-farm soil properties and coprophagous invertebrates, followed by determination of soil factors that degrade feces-borne infectious organisms. We have characterized soil biochemistry on farms and evaluated the potential effects of weather on the occurrence of chicken parasites. Our data suggest that chicken contact with soil affects levels of parasitism (see below), but there is not strong evidence that soil biochemistry is a contributing factor. Our data also indicate that wind is a strong predictor of flock infection with *Campylobacter jejuni* bacteria that cause foodborne illness. The frequency of *Campylobacter* infections is also related to the percentage of agriculture in the surrounding landscape. Poultry farms surrounded by other farms had higher frequencies of infections. These data suggest complex relationships between poultry pathogens, weather, and the surrounding landscape. We will continue to collect more data this next year using measurements of microhabitats on the farm. Objective 4: Use data collected from objectives 1-3 to develop a risk model for potential infectious diseases in poultry systems that utilize outdoor access for birds. We have used statistical models (mixed effects linear regression) to evaluate relationships between the occurrence of parasites, wild bird contact with chickens, farm management practices, soil, and weather. These analyses reveal a very complex system of factors that affect the frequency of parasite infections. Important factors include: contact between chickens and soil, the breeds of chickens in a flock, chicken age, flock density, wind, and surrounding farms. Our models represent a change in knowledge for farmers that did not previously have information about what factor(s) influenced risk of parasitic disease for their poultry. These models will ultimately help to form "best practices" for poultry farming in open environments that will maximize chicken health and minimize the need for chemical interventions (e.g. antibiotics and parasiticides). We have prepared some of these model results in manuscripts that are currently under peer review. This information is also being prepared for communication to stakeholders through extension bulletins created by eOrganic (Oregon State University). **Publications** - Type: Journal Articles Status: Published Year Published: 2019 Citation: McCulloch, J.B., Owen, J.P., Hinkle, N.C., Mullens, B.A., Busch, J.W. (2019) Genetic Structure of Northern Fowl Mite (*Mesostigmata: Macronyssidae*) Populations Among Layer Chicken Flocks and Local House Sparrows (*Passeriformes: Passeridae*). *Journal of Medical Entomology* 57: 122130, <https://doi.org/10.1093/jme/tjz136> - Type: Journal Articles Status: Published Year Published: 2020 Citation: Latimer, C., Smith, O., Taylor, J., Edworthy, A., Owen, J.P., Snyder, W.E., Kennedy, C.M. (2020) Landscape context mediates the physiological stress response of birds to farm diversification. *Journal of Applied Ecology*. doi.org/10.1111/1365-2664.13583 - Type: Journal Articles Status: Published Year

Published: 2020 Citation: Smith, O.M., Snyder, W.E., Owen, J.P. (2020) Are we overestimating risk of enteric pathogen spillover from wild birds to humans? *Biological Reviews*. 10.1111/brv.12581 - Type: Journal Articles Status: Published Year Published: 2020 Citation: Smith, O.M., Edworthy, A., Taylor, J.M., Jones, M.S., Tormanen, A., Kennedy, C.M., Fu, Z., Latimer, C.E., Cornell, K.A., Michelotti, L.A., Sato, C., Northfield, T.D., Snyder, W.E., Owen, J.P. (2020) Agricultural intensification and landscape simplification increase food safety risks imposed by wild birds on produce farms. *J. Applied Ecology*. doi.org/10.1111/1365-2664.13723 - Type: Journal Articles Status: Published Year Published: 2021 Citation: Smith, O.M., Taylor, J.M., Echeverri, A., Northfield, T., Cornell, K.A., Jones, M.S., Latimer, C.E., Owen, J.P., Snyder, W.E., Kennedy, C.M. (2021). Big wheel keep on turnin: Linking grower attitudes, farm management, and delivery of avian ecosystem services. *Biological Conservation*. doi.org/10.1016/j.biocon.2021.108970 - Type: Journal Articles Status: Published Year Published: 2021 Citation: Smith, O. M., Kennedy, C.M., Echeverri, A., Karp, D., Latimer, C., Taylor, J., Wilson-Rankin, R., Owen, J.P., Snyder, W. (2021) Complex landscapes stabilize farm bird communities and their expected ecosystem services. *J. Applied Ecology*. http://doi.org/10.1111/1365-2664.14104 - Type: Journal Articles Status: Published Year Published: 2021 Citation: Cornell, K.A., Smith, O.M., Crespo, R., Jones, M.S., Snyder, W.E., Owen, J.P. (2021) Prevalence patterns for enteric parasites of chickens managed in open environments of the Western United States. *Avian Diseases*. doi.org/10.1637/21-00079 - Type: Journal Articles Status: Published Year Published: 2021 Citation: Smith, O.M., Olimpi, E., Navarro-Gonzalez, N., Cornell, K., Frishkoff, L., Northfield, T., Bowles, T., Edworthy, A., Eilers, J., Fu, Z., Garcia, K., Gonthier, D., Jones, M., Kennedy, C M., Latimer, C., Owen, J.P., Sato, C., Taylor, J., Wilson-Rankin, E., Snyder, W.E., Karp, D. (2021) A trait-based framework for predicting foodborne pathogen spillover from wild birds. *Ecological Applications*. doi.org/10.1002/eap.2523 - Type: Journal Articles Status: Published Year Published: 2022 Citation: Chambless, K.N., Cornell, K.A., Crespo, R., Snyder, W.E., Owen, J.P. (2022) Diversity and Prevalence of Ectoparasites on Poultry from Open Environment Farms in the Western United States of Washington, Idaho, Oregon, and California. *Journal of Medical Entomology*. doi.org/10.1093/jme/tjac093 - Type: Journal Articles Status: Under Review Year Published: 2022 Citation: Laura Vang Rasmussen¹, Ingo Grass², Zia Mehrabi³, Olivia M. Smith^{4,5}, Jennifer Blesh⁶, Lucas Alejandro Garibaldi^{7,8}, Marney E. Isaac⁹, Christina Kennedy¹⁰, Rachel Bezner Kerr¹¹, Hannah Wittman¹², Peter Batory¹³, Rolando Cerda¹⁴, David Crowder¹⁵, Kevin Darras¹⁶, Kathryn DeMaster¹⁷, Karina Garcia¹⁸, David Gonthier¹⁹, Purnama Hidayat²⁰, Juliana Hipolito²¹, Lesli Hoey²², Dana James²³, Innocensia John²⁴, Andrew Jones²⁵, Daniel S. Karp²⁶, Martyna Kotowska²⁷, Yodit Kebede²⁸, Carmen Bezner Kerr²⁹, Susanna Klassen³⁰, Holger Kreft³¹, Ramiro Llanque³², Christian Levers^{30,33}, Diego Lizcano³⁴, Adrian Lu³⁵, Rosebelly Nunes Marques³⁶, Pedro Buss Martins³⁶, America Melo³⁴, Sidney Madsen³⁷, Hanson Nyantakyi-Frimpong³⁸, Elissa M. Olimpi³⁹, Jeb. P. Owen⁴⁰, Heiber Pantevez³⁴, Matin Qaim⁴¹, Sarah Redlich⁴², Christoph Scherber⁴³, Amber Sciligo⁴⁴, Sieg Snapp⁴⁵, William E. Snyder⁴⁶, Ingolf Steffan-Dewenter⁴², Anne Elise Stratton³³, Joseph M. Taylor⁴⁷, Vivian Valencia⁴⁸, Cassandra Vogel⁴², Claire Kremen⁴⁹ Agricultural diversification promotes environmental and social synergies. *Nature* (2022) Agricultural diversification promotes environmental and social synergies. *Nature* (in review) - Type: Journal Articles Status: Under Review Year Published: 2022 Citation: Achyut Adhikari, Aiko Dora Adell Nakashima, Alda Francelina Andrade Pires, Ana Allende, Angela Ferelli Gruber, Austin R. Spence, Claire Murphy, Daniel S Karp, Daniel Weller, Don Stoeckel, Donna Clements, Elissa Olimpi, Faith Critzer, Gretchen Wall, Hyatt Green, Jasna Kovac, Jeb P. Owen, Jeffery McGarvey, Kate Scow, Lisa Gorski, Matthew Jones, Naresh Devarajan, Nicole L. Arnold, Nicole Richard, Nikki W. Shariat, Nora Navarro-Gonzalez, Olivia M. Smith, Patrick Baur, Radomir Schmidt, Sandipan Samaddar, Sarah M. Beno, Sarah I. Murphy, Thao Dang-Hien Tran (2022) Evidence for the efficacy of pre-harvest agricultural practices in mitigating food-safety risks to fresh produce. *Frontiers in Sustainable Food Systems* (in review) - Type: Journal Articles Status: Under Review Year Published: 2023 Citation: Smith, O.M., Cornell, K.A., Crossley, M.S., Crespo, R., Jones, M.S., Snyder, W.E., Owen, J.P. (2023) Wind speed and agriculture mediate *Campylobacter* risk among poultry reared in open environments. *Animals* (in review) - Type: Journal Articles Status: Other Year Published: 2023 Citation: Owen, J.P., Eilers, J., Smith, O., Brunner, J. (2023) Estimating contact rates between wild birds and poultry in open environment production systems. *Poultry Science* (in preparation) - Type: Journal Articles Status: Other Year Published: 2023 Citation: Chambless, K., Konkell, M., Owen, J.P. (2023) Comparison of antibody responses to *Campylobacter* vaccination among chicken breeds associated with organic poultry farming. *Poultry Science* (in preparation) - Type: Journal Articles Status: Other Year Published: 2023 Citation: Chambless, K., Cornell, K., Owen, J.P. (2023) Health metrics among chickens raised in open environment farming systems. *Poultry Science* (in preparation) - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Chambless, K., Pautzke, K., Konkell, M., Niel, K., Fulton, J., Owen, J.P. (2022) Natural Antibody Response to Vaccination in Poultry. Presentation to Poultry Science Association, National Meeting, July 11-14, San Antonio, TX - Type: Journal Articles Status: Other Year Published: 2023 Citation: Owen, J.P., Cornell, K., Chambless, K. (2023) Emerging parasite risks during the transition to organic poultry farming. Online article for eOrganic (in preparation) - Type: Other Status: Other Year Published: 2023 Citation: Owen, J.P. and Pautzke, K. (2023) Identifying and managing parasite risks in organic poultry farming. PDF education/extension bulletins from eOrganic (in preparation) - Type: Journal Articles Status:

Published Year Published: 2019 Citation: Smith, O.M., Kennedy, C.M., Owen, J.P., Northfield, T.D., Latimer, C.E., Snyder, W.E. (2019) Highly diversified crop-livestock farming systems reshape wild bird communities. *Ecological Applications*. doi.org/10.1002/eap.2031 **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience: Nothing Reported Changes/Problems:As described in our last REEport, our field work was effectively stopped by the COVID-19 epidemic. We will be using this final year of the project to collect environmental data that will strengthen our infection risk models. We were unable to collect robust data on parasites/pathogens in wild bird species. We will use data collected on wild bird contact with chickens to model potential for transmission. We observed substantially wider variation in farming practices than we anticipated at the beginning of the project. One factor that varies considerably among farms is the choice of chicken breeds. There is evidence that susceptibility to infection varies among standard commercial chicken breeds. There is very little information about parasite resistance among the "heritage" chicken breeds that we have observed are used on open environment farms. We will use the final year of the project to evaluate variation in immune function and *Campylobacter* resistance among heritage chicken breeds, which aligns with the aims of project Objective 3: Characterize on-farm soil properties and coprophagous invertebrates, followed by determination of soil factors that degrade feces-borne infectious organisms. In that original objective, we proposed to test infectivity of bacteria in chickens. That aim will be carried out with the modification of explicitly comparing infectivity among different chicken breeds. What opportunities for training and professional development has the project provided? This project involves the training of 2 M.S. students in addition to the past training of one Ph.D. student. How have the results been disseminated to communities of interest? Scientific papers have been prepared and submitted. They are currently under peer-review. We are currently working with eOrganic (Oregon State University) on extension bulletins and web content that will communicate our results directly to stakeholders. What do you plan to do during the next reporting period to accomplish the goals? Over the next reporting period we will collect additional environmental data on farms to better understand the apparent relationships between weather, farms in the surrounding landscape, and the occurrence of *Campylobacter* infections that may be a source of human foodborne illness. In addition, we will be directly evaluating immune defense and responses to *Campylobacter* infection among poultry breeds utilized by these farms. **Impacts** What was accomplished under these goals? Project Impact: Organic production of chicken eggs and meat is a rapidly growing practice nationwide. Organic chicken egg sales more than doubled from 2014 (~166 million dozen sold) to 2017 (~399 million dozen sold). These sales reflect an increase in market value from ~\$419 million to ~\$887 million. Sales of chicken meat (broilers) from organic farms increased from ~\$372 million in 2014 to ~\$1.1 billion in 2017 (USDA National Agricultural Statistics Service). These statistics reveal that organic poultry production has grown to become a high value component of the poultry market. Importantly, many farmers are producing chickens under pastured and outdoor conditions, even though they lack USDA organic certification. A key motivation to produce chickens in these kinds of "open environments" is the appeal to consumers that believe it is healthier and more humane to raise chickens with access to foraging opportunities outdoors. An important barrier to the growth of the organic poultry market is the potential for parasites and pathogens to negatively affect production. Many parasites and pathogens that affect chickens are transmitted via feces or wildlife. These infectious organisms are controlled in conventional production systems by keeping chickens indoors where the farmer can limit chicken contact with the ground, remove feces, and block out wildlife. Under organic production, chickens can roam outdoors where they encounter soil, feces, insects, worms, and wild birds that are all potential sources of parasites and pathogens. This poses a serious risk to organic poultry production that has not been well characterized. As a result, it remains unclear what disease burdens may affect the organic poultry market and there is a lack of essential information to anticipate those risks and develop strategies to minimize disease impacts. The central objective of this research project has been to determine what parasites and pathogens may affect organic poultry production and limit the growth of the industry. The following summarizes activities and accomplishments within each of the project's main objectives over the last reporting period: Objective 1: Characterize farm landscapes using GIS-based tools, and measure frequency/duration of contact between (i) poultry and wild birds and (ii) poultry and soil. We used statistical models to evaluate the wild bird species most observed contacting chickens in open environments. Of 91 wild bird species observed near poultry flocks, only 15 species exhibited regular contact with chickens. These data suggest it may be possible for farmers to develop targeted mitigation strategies to discourage wild bird contact with chickens, while also supporting bird diversity that is an important ecosystem service that many organic farmers seek to strengthen. These accomplishments represent a change in knowledge for farmers that previously lacked information about (i) the diversity and abundance of parasites that may affect flocks in open environments and (ii) the wild bird species that most frequently interact with chickens on the farm to create avenues for parasite introduction. With this change in knowledge, farmers and researchers will be better equipped to develop mitigation strategies to limit the impacts of these parasitic diseases and lower the barriers to growth of the organic poultry market. This information has been prepared in a manuscript that is currently under peer-review. This information is also being prepared for communication to stakeholders through extension bulletins created by eOrganic (Oregon State University). We determined that chicken contact with the soil was strongly influenced by farm management practices (e.g. flock

rotation frequency), flock size, and chicken breed (meat versus layer). Importantly, we found that chicken-soil contact was highly varied among farms and that no single factor among the farms was a determinant of the duration of chicken-soil contact. This is important, because it indicates the reduction of parasite risk cannot be accomplished through modification of any single farming practice. Instead, management of parasitic disease on open environment poultry farms will have to be accomplished by consideration of the farming system. These results represent a change in knowledge for farmers that previously lacked information about the multiple ways that on-farm practices could affect risk of parasite exposure. This information has been prepared in a manuscript that is currently under peer-review. This information is also being prepared for communication to stakeholders through extension bulletins created by eOrganic (Oregon State University).

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Objective 4: Use data collected from objectives 1-3 to develop a risk model for potential infectious diseases in poultry systems that utilize outdoor access for birds. We have used statistical models (mixed effects linear regression) to evaluate relationships between the occurrence of parasites, wild bird contact with chickens, farm management practices, soil, and weather. These analyses reveal a very complex system of factors that affect the frequency of parasite infections. Important factors include: contact between chickens and soil, the breeds of chickens in a flock, chicken age, flock density, wind, and surrounding farms. Our models represent a change in knowledge for farmers that did not previously have information about what factor(s) influenced risk of parasitic disease for their poultry. These models will ultimately help to form "best practices" for poultry farming in open environments that will maximize chicken health and minimize the need for chemical interventions (e.g. antibiotics and parasiticides). We have prepared some of these model results in manuscripts that are currently under peer-review. This information is also being prepared for communication to stakeholders through extension bulletins created by eOrganic (Oregon State University).

****Publications**** - Type: Journal Articles Status: Published Year Published: 2020 Citation: Smith, O.M., Edworthy, A., Taylor, J.M., Jones, M.S., Tormanen, A., Kennedy, C.M., Fu, Z., Latimer, C.E., Cornell, K.A., Michelotti, L.A., Sato, C., Northfield, T.D., Snyder, W.E., Owen, J.P. (2020) Agricultural intensification and landscape simplification increase food safety risks imposed by wild birds on produce farms. *J. Applied Ecology*. doi.org/10.1111/1365-2664.13723 - Type: Journal Articles Status: Published Year Published: 2021 Citation: Smith, O.M., Taylor, J.M., Echeverri, A., Northfield, T., Cornell, K.A., Jones, M.S., Latimer, C.E., Owen, J.P., Snyder, W.E., Kennedy, C.M. (2021). Big wheel keep on turnin: Linking grower attitudes, farm management, and delivery of avian ecosystem services. *Biological Conservation*. doi.org/10.1016/j.biocon.2021.108970 - Type: Journal Articles Status: Accepted Year Published: 2021 Citation: Smith, O.M., Olimpi, E., Navarro-Gonzalez, N., Cornell, K., Frishkoff, L., Northfield, T., Bowles, T., Edworthy, A., Eilers, J., Fu, Z., Garcia, K., Gonthier, D., Jones, M., Kennedy, C.M., Latimer, C., Owen, J.P., Sato, C., Taylor, J., Wilson-Rankin, E., Snyder, W.E., Karp, D. (2021) A trait-based framework for predicting foodborne pathogen spillover from wild birds. *Ecological Applications*. - Type: Journal Articles Status: Under Review Year Published: 2021 Citation: Smith, O. M., Kennedy, C.M., Echeverri, A., Karp, D., Latimer, C., Taylor, J., Wilson-Rankin, R., Owen, J.P., Snyder, W. (2021) Complex landscapes stabilize farm bird communities and their expected ecosystem services. *J. Applied Ecology*. - Type: Journal Articles Status: Under Review Year Published: 2021 Citation: Cornell, K.A., Smith, O.M., Crespo, R., Jones, M.S., Snyder, W.E., Owen, J.P. (2021) Prevalence patterns for enteric parasites of chickens managed in open environments of the Western United States. *Avian Diseases*.

PROGRESS

2017/09 TO 2018/08 Target Audience: The target audiences include organic poultry farmers, and researchers working in the areas of disease ecology and agriculture. Efforts to reach these audiences include the production of extension/outreach reports to individual farmers that describe (i) the measured levels of infection observed on their farms, (ii) the relevant biological background information for the observed disease risks, and (iii) suggested mitigation strategies to limit the effects of the parasites on their flocks. In addition, preliminary data were reported by a graduate student at the International Ornithological Congress to draw researcher attention to the potential disease interactions between wild birds and poultry. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? One M.S. student has been involved with sample and data collection from farms. The graduate student was assisted by a field technician. Two undergraduate students have been involved with data management, collection of blood cell data (via microscopic examination of blood films), and development/implementation of antibody screening in collected serum via enzyme-linked immunosorbent assays (ELISAs). How have the results been disseminated to communities of interest? Reports of detected parasites and pathogens have been provided to farmers involved with the project. These reports summarize the data recorded from the respective farm and provide a summary of the relevant background information on potential health effects that could impact the farmer. When possible, suggested strategies for mitigating health effects and future infection are included in the reports. What do you plan to do during the next reporting period to accomplish the goals? Based on the data collected in 2018, we will focus sample collection efforts in 2019 to target specific wild bird species that we believe are involved with parasite/pathogen exchange with poultry. In addition, we will begin empirical tests of the effects of soil properties on the persistence of the parasites observed in the field (Objective 3).

IMPACT

2017/09 TO 2018/08 What was accomplished under these goals? Twenty-eight organic poultry farms located across California, Oregon, and Washington States were visited to collect samples and data that are relevant to project objectives 1 and 2. The collected samples included flock fecal samples in the environment, blood samples from individual birds in each flock, and soil samples from areas with and without poultry. Fecal samples have provided direct detection of bacteria (*Campylobacter* and *Salmonella*), *Coccidia* parasites, and intestinal worms. Additional data collected include point-counts of wild birds on the farm, and counts of wild bird contact with poultry. Finally, data on farm management were collected through the use of farmer surveys and interviews. **PUBLICATIONS (not previously reported):** 2017/09 TO 2018/08 No publications reported this period.

[↑ Return to Index](#)