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PROJECT INDEX

Integrating Biorational Approaches to Control Plant Parasitic Nematodes and Weeds in Organic Vegetable Systems

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NON-TECHNICAL SUMMARY

Plant-parasitic nematodes and weeds are critical yield-limiting pests of organic vegetables in the United States. This project proposes a broad-based coordinated research program to control nematodes and weeds in organic vegetable production systems in Georgia, which will simultaneously benefit to organic producers in the southern United States. Our overall goal is to discover and integrate both new and commercially available biological products, and suppressive cover crops to develop a successful nematode and weed management program that growers can adopt for organic vegetable production. We will identify Bacillus thuringiensis (Bt) crystal proteins, entomopathogenic nematodes (EPNs) and EPN bacterial metabolites for root-knot nematode (Meloidogyne spp.) control. We will determine if combining cover crops with different microbial treatments will improve control of both nematodes and weeds. We will also implement cost-return analyses to demonstrate that our integrated management practices are profitable tools for organic vegetable growers. Technology-transfer and extension activities will include presentations at grower, scientific and industry venues to facilitate adoption of this innovative control method.

OBJECTIVES

The specific objectives of this project are as follows: Identify native Bacillus thuringiensis (Bt) strains with high nematicidal activity against root-knot nematode Meloidogyne incognita in vitro. Pot evaluation of Bt strains, entomopathogenic nematodes (EPNs) and their bacterial metabolites, as well as commercially available biological/botanical nematicides for root-knot nematode control. Evaluate the effect of summer and winter cover crops on population density of nematodes and weeds under field conditions. Integrate the best practices of cover cropping and the most effective biological products and microbial treatments of Bt, EPN and EPN metabolite to control nematodes and weeds in organic production of vegetables. Evaluate the economic profitability of the developed practice(s), extension and outreach activities and involvement of an Advisory Board for project evaluation.

APPROACH

Objective 1. Identify native Bacillus thuringiensis (Bt) strains with high nematicidal activity against root-knot nematode Meloidogyne incognita in-vitro. NativeBt strains will be scaled up and grown to spore crystal lysates for mortality activity assays. M. incognita J2 will be exposed to 10, 100, and 500 ug/ml of Bt Cry proteins, and mortality will be determined visually under an inverted microscope at 2 days and 4 days post exposure. Each treatment will be replicated four times and the test will be performed twice. Negative controls will include water and non-crystal forming Bt. The mortality rates (M) of J2 will be calculated using Abbott\'s formula. Two top Bt strains causing the greatest mortality to M. incognita will be tested in more extensive dose-response assays and subsequently used for pot evaluations.Objective 2. Pot evaluation of Bt strains, entomopathogenic nematodes (EPNs) and their bacterial metabolites, as well as commercially available biological/botanical nematicides for nematode control.Sub-objective A. Determine the efficacy of commercially available biological/botanical products for control of root-knot nematode.Two independent trials will be conducted in the greenhouse using commercially available biological and botanical products. The trials will utilize a completely randomized design with five replicates per treatment. Tomato (cv. Rutgers) plants will be infected with 1000 M. incognita J2, and soil drench applications of nematicides will be done twice: at transplanting and 2 weeks after transplanting. After 8 weeks, shoot length, shoot dry weight, phytotoxicity, and crop yield will be evaluated. Phytotoxicity will be rated visually one week after application of microbial treatments using a 0 to 5 scale. Root gall severity will be evaluated using a 0 to 5 scale. Data will be analyzed and two most efficacious biological products will be selected for Obj. 3.Sub-objective B. Determine the nematicidal activity of top selected Bt strain as well as EPNs and their bacterial metabolites on root-knot nematode Meloidogyne incognita.A greenhouse study will be conducted to test the efficacy of application rate (low and high) and time (5 days before transplanting and at transplant) of two best Bt strains, identified in Obj. 1, as well as two EPNs (S. riobrave and S. carpocapsae) and their bacterial metabolites (X. cabanillasii and X. bovienii, respectively) against M. incognita.Tomato (cv. Rutgers) seedlings will be grown in polyethylene pots filled with steamed field soil and then inoculated with 1,000 M. incgonita J2. Plants treated with water will be considered as control. At 8 weeks after transplanting, data on plant height, root dry weight, phytotoxicity, and gall severity will be evaluated as described in Sub-obj. A. Data will be analyzed and the most efficacious Bt strain and EPN treatment will be selected for Obj. 3 (field studies).Objective 3. Evaluate the effect of summer and winter cover crops on population density of nematodes and weeds under field conditions. This study will be conducted in a certified organic field naturally infested with Meloidogyne spp., at the UGA Horticulture Hill Farms, Tifton, GA to determine the effect of different termination timing of cover crops on development and population of nematodes and weed density. There will be three cover crop treatments arranged in a completely randomized design with five replications, including a fallow treatment. Sunn hemp (AU Golden), marigold (Cracker Jack) and sesame (Benne) will be used as summer cover crops, and oilseed radish (Carwoodi), oat (Tachibuki) and rye (Wrens Abruzzi) as winter cover crops. Winter cover crops will be grown in the field in early October and harvested90 and 120 days after planting. Summer cover crops will be grown in early April and terminated 60 and 80 days after planting.Cover crop residues will then be incorporated into soil by a moldboard plow. Two weeks after incorporation, planting bedswill be prepared to stimulate weeds to germinate. Data collected will be cover crop biomass accumulation, abundance of plant-parasitic nematodes, root galling severity, and weed density. Each previous cover crop and fallow plot will then be split and a post-emergence OMRI-certified herbicide \"Suppress EC\" will be applied at a labeled rate to one row.The remaining one row will be left untreated. Visual estimates of weed controlwill be made for two weeks. Data will be analyzed and the most suppressive winter and summer cover crops will be selected for on-farm studies in Obj. 4.Objective 4. Integrate the best practices of cover cropping and most effective biological products, and microbial treatments of Bt and EPN to control nematodes and weeds in organic production of vegetables.An on-farm trial will be initiated in year 2 and repeated in year 3 in a grower farmto evaluate the best treatments identified in objectives above and develop an effective management program that organic growers can adopt for vegetable production.The most suppressive winter and summer cover crops from Obj. 3 will be grown in the fall and spring preceding the spring and summer production of cabbage and tomato, respectively.In-season treatments will be the top selected Bt strain, bacterial metabolite of EPNand two biological/botanical product. The dimensions of plots will depend on what spacing works best for the cooperator grower. Plots will be arranged in a completely randomized design with five replicates for each cover crop. The cover crop termination timing will be based on the results from Obj. 3. After termination, plants will be cut from the soil surface and incorporated into soil.In the winter and summer of Year 2 and 3, each previous cover crop plot will be split and in-season treatments will be applied to one row using a drip irrigation system. In-season treatments will be the top selected Bt strain, EPN metabolite and biological/botanical product as well as an untreated check.Population densities of plant-parasitic nematodes, weed density, cover crop biomass, crop yields and soil biochemical properties will be evaluated.Objective 5. Evaluate the economic profitability of the developed practice(s), extension and outreach activities and involvement of an advisory board for project evaluation.The economic feasibility and efficacy of sustainable treatment alternatives (biological products, cover cropping, and microbial treatments) for managing nematodes and weeds in organic production of vegetables will be investigated using a combination of the trial data collected through the project and market cost data. The economic methods and analysis that will be considered in this study include farm enterprise budging and cost-benefit analysis.Educational materials include extension bulletins, popular research reports, trade magazinesand individual or group discussions with growers. Communications will commence immediately as data become available and will continue after the grant cycle ends.We maintain a very strong commitment to publish research results in peer-reviewed journals. The work we propose here will result in at least three technical papers. The investigators routinely present abstracts and posters at the annual scientific meetings. Progress 09/01/20 to 08/31/24 Outputs Target Audience:The project\'s target audience encompasses Extension agents and growers in Georgia, Florida, and neighboring states. The results of this project will be valuable to a range of stakeholders, including Extension specialists seeking to enhance their knowledge and advisory services, County extension agents working directly with growers, crop consultants and professionals looking for evidence-based solutions, and industry cooperators interested in advancing best practices of managing nematode and weed pests. The project aimed to drive regional and national adoption and impact by engaging with these stakeholders. Changes/Problems:N/A What opportunities for training and professional development has the project provided?This project was supported by a team of researchers, including two Ph.D. students, Josiah Marquez and Denis Gitonga, who were hired to work on the project. Additionally, Colin Wong, a postdoctoral fellow at the USDA-ARS in Byron, GA, contributed to a portion of the project. The team was further assisted by three research technicians/biologists and several research interns who played a crucial role in the project\'s success. How have the results been disseminated to communities of interest?The findings of this project were disseminated widely to stakeholders and the scientific community through various channels, including presentations at annual regional, national, and international conferences and meetings, County growers\' meetings and extension agent training sessions, cover crop workshops and field days, scientific and extension publications, and industry magazines. This multi-faceted approach ensured that the results reached a broad audience, facilitating knowledge sharing and uptake among diverse stakeholders. What do you plan to do during the next reporting period to accomplish the goals?N/A Impacts What was accomplished under these goals? The specific objectives of this project were 1) evaluate the efficacy of native Bacillus thuringiensis (Bt) crystal proteins, bacterial metabolites associated with entomopathogenic nematodes (EPNs), and OMRI-certified bionematicides for control of root- knot nematode (RKN), Meloidogyne incognita under in vitro and greenhouse conditions, 2) evaluate the effect of summer and winter cover crops on the population density of nematodes and weeds under field conditions, 3) integrate the best practices of cover cropping, most effective biological products and EPN bacterial metabolite to control nematodes in organic production of vegetables, and 4) evaluate the economic profitability of the developed practices. The outcomes of this project are summarized below. Three studies were conducted to meet the first objective: First, we examined the nematicidal effects of spore/crystal proteins from four B. thuringiensis strains against RKNs. Thestrains were isolated from U.S. soils and sporulated in PGSM medium. Then the expression of Cry5B, Cry6A, Cry14A, and Cry21A proteins was confirmed by SDS-PAGE. Each of two separate bioassays involved 100 M. incognita second-stage juveniles (J2) exposed to various concentrations (25, 50, or 100 μg/ml) of Bt proteins. Negative and positive controls included water, non-crystal-forming Bt strain HD1 (4D8), and Fluopyram, respectively. After 48 and 96 hrs, Cry5B showed the highest nematicidal activity, followed by Cry6A, with Cry14A and Cry21A showing the least. Nematode mortality was significantly higher after 96 hrs, with only 100 μg/ml being the most effective concentration. This suggests that Bt Cry proteins have potential as biological control agents against PPNs, warranting further studies in greenhouse and field conditions. Next, we evaluated metabolites from Xenorhabdus szentirmaii and X. bovienii bacteria on cabbage against M. incognita under different application timings \5 days before planting (DBP) and at planting (AP)\ in greenhouse and screenhouse conditions. For comparison, bionematicides, (MeloCon WG and Majestene)and a chemical nematicide, Vydate, were only applied at planting. Plants treated with only water served as untreated check. Plants were infected with 1,000 RKNs, soil-drenched with metabolites or nematicides, and grown for 450-degree days at 10°C to complete two generations. The metabolites and Vydate significantly reduced root galling and egg counts/gram of root compared to Majestene and MeloCon, particularly when applied 5 DBP in the greenhouse. Both metabolites and Vydate reduced egg counts at AP and 5 DBP in the greenhouse, but no differences were observed in the egg counts between the metabolites and Vydate at 5 DBP in the screenhouse, showing potential for nematode control under varying application timings. Lastly, the efficacy of eight OMRI-certified bionematicides (Majestene, TerraNeem, AzaGuard, Molt-X, NemOmex, EcoWorks, Monterey, and Promax) was tested on M. incognita in tomatoes in the greenhouse for eight weeks. AzaGuard and Majestene improved root weights, with Monterey showing the lowest root weights and galling indices. Also, AzaGuard and TerraNeem- treated plants had the lowest eggs/gm of roots compared to the positive control. Field trials were recommended for further exploration of AzaGuard, EcoWorks, NemOmex, and Promax. The second objective was accomplished by conducting the following two field trials. A field study (2019-2021) assessed the effects of cover crops, weedy fallow rotations, and tillage practices on soilborne diseases and nematodes in spring tomatoes, fall squash, and winter cabbage. The trialused a split-plot 2 × 4 factorial randomized complete block design (RCBD), with shallow or deep tillage applied to whole plots. Subplots included rotation type (cover crop or weedy fallow) and season, with spring or fall sunn hemp and winter rye as cover crops. Sunn hemp and weedy fallow rotations significantly reduced RKN populations and root galling in the first vegetable crop, regardless of tillage. These rotations had limited impact on fungal pathogens. Fall-planted sunn hemp led to higher plant biomass and reduced galling in the second crop. Both spring and fall sunn hemp increased yields, while winter rye significantly reduced ring nematode (Mesocriconema spp.) populations in the first crop. Deep tillage reduced fungal pathogens (Rhizoctonia solani and Sclerotinia sclerotiorum) and lowered stubby-root nematode (Nanidorus minor) populations. Sunn hemp was especially effective in suppressing M. incognita. The study suggests sunn hemp is more effective than winter rye in suppressing RKNs, particularly in the fall, but both cover crops had limited effects on fungal pathogens. A two-year field study (2021-2022) evaluated winter cover crops and a bioherbicide for managing PPNs and weeds. The trials were conducted during two consecutive winter seasons, using oilseed radish, oat, rye, mustard, a rye-oat mix, and fallows (with and without weeds), each replicated five times. Cover crops were incorporated at 90 and 120 days. Rye and oat, especially in combination, significantly reduced M. incognita populations and suppressed weeds like corn spurry. Mustard and radish had variable effects on nematodes, sometimes increasing populations. Extending cover crop duration to 120 days increased nematode populations but reduced weed densities. The study highlights rye and oat as effective cover crops for nematode and weed control in organic vegetable systems. Two field trials explored integrating nematode-suppressive cover crops (\'Crescent Sun\' sunn hemp and \'Sweet Six BMR\' sorghum-sudangrass) with three bionematicides (AzaGuard, Promax, EcoWorks) and a metabolite from X. bovienii (XB) bacteria for managing PPNs in organic zucchini. Treatmentsincluding two cover crops, bionematicides, and controls, were arranged in RCBD with five replications. Results showed that combining sorghum-sudangrass and sunn hemp with Promax and EcoWorks significantly reduced Meloidogyne and Hoplolaimus populations compared to fallow treatments, though Criconema populations increased in sorghum-sudangrass plots. Weedy fallow and the sunn hemp + sorghum-sudangrass + XB treatments had the highest nematode populations. No significant yield differences were observed. This suggests combining cover crops with bionematicides is effective, though cover crop selection is crucial to avoid increasing specific nematode populations. In addition, economic analyses were performed to address the fourth objective of this project. For an economic analysis, we synthesized results from field trials with current market prices for inputs and commodities. This included evaluating the returns of using cover crops to improve the profitability of organic zucchini production. Market prices were sourced from recent University of Georgia enterprise budgets (2022-2024), USDA data, and University Extension specialists. Trials integrated sunn hemp, sorghum-sudangrass, and four bionematicides. Establishment and removal costs for cover crops were estimated at \$160 per acre, while bionematicide prices ranged from \$20 to \$160 per acre. Although cover crops and bionematicides increased per-acre costs, a statistically significant yield increase could enhance profitability due to zucchini\'s high market value. Conventional zucchini in Georgia fetches a median price of \$13.00 per 30-lb box, with organic growers earning a 30% premium. The trials did not show a clear advantage for one cover crop, but AzaGuard consistently performed well. To cover additional costs, 300 lbs more per acre would be needed at the median price. At higher prices, this drops to 280 lbs; at lower prices, it rises to 350 lbs. In summary, while no definitive management strategy emerged from the trials, the high market value of organic zucchini offers potential profitability, which may offset the extra input and management costs. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Gitonga, D., Hamidi, N., and A. Hajihassani, A. 2021. Efficacy of certified bionematicides for control of Meloidogyne incognita in the greenhouse conditions. Journal of Nematology 53: 11. . Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2024 Citation: Jagdale, G. B., Wong, C., Hajihassani, A. and Shapiro-Ilan, D. 2024. Influence of bacterial metabolites from entomopathogenic nematode antagonism against Meloidogyne javanica in tomato under greenhouse conditions. Plant Health 2024- Annual Meeting of the American Phytopathological Society, Memphis, TN July 27- 30, 2024. Type: Conference Papers and Presentations Status: Other Year Published: 2021 Citation: Marquez, J., and Hajihassani, A. Pyramiding cover crop rotation of sunn hemp or rye with tillage practices for suppression of nematodes, fungal soil-borne diseases, and weeds in a bare-ground vegetable production system. The 66th Annual Conference on Soilborne Plant Pathogens and the 51st Annual Statewide California Nematology Workshop, March 23-24, 2021. Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: Hajihassani, A., Timper, P., and Shapiro-Ilan, D. 2022. Effects of application timing on the efficacy of Xenorhabdus metabolites for control of Meloidogyne incognita. The 7th International Congress of Nematology, 1-6 May 2022, Antibes Juan-Les-Pins, France. Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: Gitonga, D., Hamidi, N., and Hajihassani, A. Evaluation of the effect of winter cover crops on population density of Meloidogyne incognita under field conditions. Annual Meeting of the Society of Nematologists. September 26-29, 2022, Anchorage, Alaska. Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: Marquez, J., Coolong, T.W. Dutta, B., and Hajihassani, A. Root-knot nematode suppression and effects on soil food web by cover crop and tillage practices in a bare-ground vegetable production system. 7th International Congress of Nematology, May 1-6, 2022. Antibes Juan-les-Pins, France. Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Hajihassani, A. 2024. Effects of off-season winter cover crops and in-season nematicide application on plant-parasitic nematodes. Annual Meeting of American Society for

Horticultural Science. September 23-27, 2024, Honolulu, Hawaii. Type: Journal Articles Status: Published Year Published: 2023 Citation: Marquez, J. and Hajihassani, A. 2023. Successional effects of cover cropping and deep tillage on suppression of plant-parasitic nematodes and soilborne fungal pathogens. Pest Management Science. 79: 2737-2747. Type: Journal Articles Status: Published Year Published: 2022 Citation: Marquez, J., Hajihassani, A., and Davis, R. F. 2022. Evaluation of summer and winter cover crops for variations in host suitability for Meloidogyne incognita, M. arenaria and M. javanica. Nematology, 24: 841-854. Type: Journal Articles Status: Published Year Published: 2020 Citation: Kicklighter, J., Kichler, J.M., and Hajihassani, A. 2020. On-farm evaluation of sunn hemp cover cropping on root-knot nematodes, 2018. Plant Disease Management Reports, 14: N030. Progress 09/01/22 to 08/31/23 Outputs Target Audience:The target audience for this project is organic vegetable growers and producers in Georgia, Florida, and the neighboring Southern states. However, the results will be used by extension specialists, county extension agents, crop consultants, Ag. Professionals and the industry. Changes/Problems:Because of the relocation of the former PD from Georgia to Florida, we were unable to include an on-farm trial because no certified organic vegetable farm with root-knot nematode infestation was found in South Florida. What opportunities for training and professional development has the project provided?This project has helped to fund and train two graduate students. Also, two research interns from minority-serving institutions (Miami Dade College and Broward College) were hired to work on this research. All students were trained and integrated in every aspect of the project. One post-doc and one technician are also assisting with the project. How have the results been disseminated to communities of interest?Dr. Hajihassani presented some results from this project on using cover crops for nematode control at the Florida Ag Expo attendees (\>250) at the Gulf Coast Research and Education Center on November 2, 2022. The results from the bacterial metabolite research were shared with others at the Entomological Society of America, Southeastern Branch, March 12-15, 2023, in Little Rock, Arkansas. Two abstracts were presented at the 7th International Congress of Nematology and Society of Nematologists annual meeting. What do you plan to do during the next reporting period to accomplish the goals?We are currently conducting field studies in two locations in central and south Florida on the integration of cover crops and bionematicides for nematode control. These experiments will be completed in spring 2024. Also, the economic analyses of the project will be completed. A manuscript will be prepared for submission and results will be presented at field days and scientific meetings. Impacts What was accomplished under these goals? A field study in a randomized complete block design with five treatments \oilseed radish (cv. Carwoodi), oat (Tachibuki), rye (Wrens Abruzzi), mustard (Caliente), and rye-oat mixture\ was established to examine the evaluation of the effect of winter cover crops on the population density of root-knot nematode (RKN), Meloidogyne incognita. Two fallows (with and without weeds) were included as controls. The cover crops were planted in early October and terminated 90 and 120 days after planting. Cover crop residues were then incorporated into the soil by a moldboard plow to achieve a maximum volume of allelopathic and/or nematicidal activity. RKN population densities were examined before planting, at termination, and two weeks after incorporating the crop residue into the soil. Biomass accumulation was determined using 10 random representative plants at the termination of cover crops. Oven-dried aboveground parts of plants were weighed, and their root systems were assessed for RKN gall severity. The RKN abundance differed (P \< 0.01) between the two years (2021 and 2022). In 2021, there was an increase in the nematode population (P \< 0.05) when the cover crops were left longer (120 days) in the field compared to a shorter period (90 days). The incorporation of cover crops in the soil was not significant in terms of RKN abundance in both trials. In 2021, rye-oat had the lowest RKN abundance (P \< 0.01) compared to other treatments, while radish had the highest abundance (P \< 0.01). There were no significant differences in the nematode density between rye, mustard, and the two fallows. In 2022, RKN abundance was not significantly affected by either the termination period (90 and 120 days) or cover crop incorporation in the soil. However, there were differences among the treatments with the fallow with weeds having the highest RKN abundance (P \< 0.01) compared to other treatments. Oat, rye, and fallow without weeds had the lowest RKN abundance. The cover crop biomass was significantly higher in 2021 than in 2022, with radish having the highest biomass. Mustard had a higher galling index (P \< 0.01) than other cover crops in both 90 and 120 termination days, while oat, rye, and rye-oat mixture had the lowest galling index. We found that rye and rye-oat mixture can reduce M. incognita populations in the soil. Two plasticulture field trials were conducted to evaluate the nematicidal efficacy of selected commercially available bionematicides against M. incognita. The products included AzaGuard, EcoWorks, NemOmex, Promax, and Pendi selected using a greenhouse screening test, and Vydate was used as the standard control. The trials were conducted in a field naturally infested with Meloidogyne incognita. The trial consisted of two bionematicide application regimes (calendar vs. nematode development based). The experiment utilized a randomized complete block design with five replicates per treatment. The average daily soil temperature at a depth of 5, 10, and 20 cm was assessed for the nematode development-based application. Accumulated degree days of 370 to 380 were achieved for M. incognita to complete one generation, at which the nematicides were applied according to the label through the drip irrigation system. Soil nematode abundances were assessed three times at pre-plant, midseason, and harvest, while root galling was assessed at mid-season and harvest. The crop yield was also determined by harvesting cucumber three times during the season. Nematode development-based applications had lower M.

incognita density at harvest than calendar-based applications. Moreover, AzaGuard, EcoWorks, and Vydate had the lowest nematode density compared to other treatments. The gall index and yield differed significantly among all treatments in both application regimes. These results suggest that the nematode development-based application reduces M. incognita population density and the frequency of application compared to calendar-based applications. Additionally, AzaGuard and EcoWorks consistently reduced M. incognita population density under greenhouse and field conditions; therefore, they can be used in an integrated pest management approach to control M. incognita. In another study, we investigated the potential use of crystal toxins of Bacillus thuringiensis (Bt) to control root-knot nematode, Meloidogyne incognita. Four different native Bt strains expressing nematode-active toxins from different soils collected from all over the world were sporulated for 96 hours at 30° C in PGSM medium and their nematicidal effects were studied in vitro against the nematode.These strains express Cry5B, Cry6A, Cry14A, and Cry21A proteins known to be active against nematodes, and expression of the proteins was confirmed by SDS PAGE. In addition, the canonical B. thuringiensis HD1 strain 4D8 cured of all Cry protein plasmids (i.e., expresses no Crystal proteins) was similarly grown.The bioassays were conducted in 24-well plates. M. incognita J2 was exposed to 25, 50, and 100 ug/ml of the four Bt Cry proteins. Each well received 500 µl of each Bt concentration, to which 90 - 100 nematodes in 70 µl distilled water were added. Each treatment was replicated four times and the experiment was performed twice. Negative controls included water and non-crystal forming Bt; positive control included a known nematicide (velum). The mortality was determined visually under an inverted microscope at 48 hours and 96 hours post-exposure.Nematodes were considered dead if their body was straight and they did not respond to being touched by a small probe. The mortality rates (M) of J2 were calculated using Abbott\'s formula. We found that the crystal proteins of isolate Cry5B showed the highest nematicidal activities across all the concentrations followed by Cry6A while crystal proteins of isolate Cry14A and Cry21A had the least nematode mortality in all Bt concentrations. Moreover, after examining the time of exposure in the four Bt crystal proteins, it was evident that 96 hours post-exposure had a significant increase in nematode mortality compared to 48 hours post-exposure across all treatments with 100 ug/ml being the most effective concentration compared to 25 ug/ml and 50 ug/ml. It was also observed that the nematodes did not recover after 24 hours upon adding 1ml water into wells containing 500 µl of each Bt concentration. Publications Type: Journal Articles Status: Published Year Published: 2023 Citation: Marquez, J. and Hajihassani, A. 2023. Successional effects of cover cropping and deep tillage on suppression of plant-parasitic nematodes and soilborne fungal pathogens. Pest Management Science. https://doi.org/10.1002/ps.7450 Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Hajihassani, A., Gitonga, Timper, P., and Shapiro-Ilan, D. Effects of application timing on the efficacy of Xenorhabdus and Photorhabdus metabolites for control of Meloidogyne incognita. 7th International Congress of Nematology, May 16, 2022. Antibes Juan-les-Pins, France. Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: Gitonga, D., and Hajihassani, A. 2023. Efficacy of bionematicides against Meloidogyne incognita under greenhouse and field conditions 2023 Society of Nematologists meeting, July 9-14, Columbus, OH. Type: Journal Articles Status: Published Year Published: 2022 Citation: Marquez, J., Hajihassani, A., and Davis, R. F. 2022. Evaluation of summer and winter cover crops for variations in host suitability for Meloidogyne incognita, M. arenaria and M. javanica, Nematology, 24: 841-854. doi: https://doi.org/10.1163/15685411-bja10172 **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:The target audience for this project is Extension agents and growers in Georgia, Florida, and the neighboring states. The results will be used by extension specialists, county extension agents, crop consultants and professionals, and industry cooperators to manage nematode problems. Changes/Problems: Since the former PD, Dr. Hajihassani, moved from the University of Georgia to the University of Florida and the presence of different environmental conditions between South Georgia and South Florida, the objective of the effects of summer cover crops for the control of plant-parasitic nematodes and weeds cannot be completed. We also should search for, if available, an organic vegetable grower in South Florida to conduct on-farm trials (last objective) for integrated management of nematodes and weeds using both biopesticides and cover crops. If no organic vegetable farm is located, this objective will be examined in a certified organic field in one of the University of Florida's research centers. What opportunities for training and professional development has the project provided? A Ph.D. student (Denis Gitonga) was hired from the proposal and is currently working on the project at the University of Georgia. This student was transferred with Dr. Hajihassani to the University of Florida and will be working on completing the laboratory and field studies. A postdoctoral fellow (Colin Wong) is currently working on a portion of the project at the USDA-ARS in Byron, GA. In addition, two research technicians/biologists were able to assist in the preparation of Bt cry isolates and EPN metabolites at the UMass Medical School and USDA-ARS, Byron, GA, respectively. How have the results been disseminated to communities of interest?The results of the study on the effect of bacterial symbionts of entomopathogenic nematodes on root-knot nematode control were presented by Dr. Hajihassani at the Seventh International Congress of Nematology in May 2022 in Antibes Juan-Les-Pins, France. In addition, Dr. Hajihassani presented the findings from this project at multiple county growers' meetings in Georgia in Winter 2021. Also, he developed a virtual cover crop training workshop and presented the results to the University of Georgia's Extension agents. Dr. Hajihassani also was invited to the Southeast Regional Fruit and Vegetable Conference in

Savannah in January 2022 and shared part of the results with growers, Extension agents, the agriculture community, and the industry. An article was published in AgNet Media magazine titled \"Cover Crops for Summer Nematode Management\". This article reveals some of the results from this project and can be found on the following link: <https://specialtycropindustry.com/cover-crops-for-summer-nematode-management/> What do you plan to do during the next reporting period to accomplish the goals? Conduct greenhouse studies for root-knot nematode control using Bt toxins. Conduct field studies using the integrated management practices developed in this project. Conduct the economic analysis, prepare manuscripts, and continue sharing the results with stakeholders and the scientific community. **Impacts** What was accomplished under these goals? Bioassay to test the effect of Bacillus thuringiensis on mortality of Meloidogyne incognita in vitro. To investigate the potential use of crystal toxins of Bacillus thuringiensis (Bt) to control plant-parasitic nematodes, we studied the nematicidal effects of spore/crystal proteins of four Bt isolates were studied in vitro against Meloidogyne incognita nematode. Four different native Bt strains expressing nematode-active toxins from different soils collected in the US were sporulated for 96 hours at 30° C in PGSM medium. These strains express Cry5B, Cry6A, Cry14A, and Cry21A proteins known to be active against nematodes, and expression of the proteins was confirmed by SDS PAGE. In addition, the canonical B. thuringiensis HD1 strain 4D8 cured of all Cry protein plasmids (i.e., expresses no Crystal proteins) was similarly grown. The bioassays were conducted in 24-well plates. M. incognita J2 was exposed to 25, 50, and 100 ug/ml of the four Bt Cry proteins. Each well received 500 μl of each Bt concentration, to which 90 - 100 nematodes in 70 μl distilled water were added. Each treatment was replicated four times and the experiment was performed twice. Negative controls included water and non-crystal forming Bt; positive control included a known nematicide (Velum). The nematode mortality rate was determined visually under an inverted microscope at 48 and 96 hours post-exposure. The crystal proteins of isolate Cry5B showed the highest nematicidal activities across all the concentrations followed by Cry6A, while crystal proteins of isolate Cry14A and Cry21A had the least nematode mortality in all Bt concentrations. Moreover, after examining the time of exposure in the four Bt crystal proteins, it was evident that 96 hours post-exposure had a significant increase in nematode mortality compared to 48 hours post exposure across all treatments with 100 ug/ml being the most effective concentration compared to 25 ug/ml and 50 ug/ml. It was also observed that the nematodes did not recover after 24 hours upon adding 1ml water into wells containing 500 μl of each Bt concentration. ? Effects of metabolites cultured from the bacterial symbionts of entomopathogenic nematodes on root-knot nematodes. Bacteria were isolated from five different strains of entomopathogenic nematodes, all of which are commercially available. Bacteria were grown for 8 days, and the exo-metabolites found in the growth medium were used for the experiments. The metabolite broths and control treatments were co-applied with the root-knot nematode, Meloidogyne incognita to young tomato plants (Rutgers, a susceptible variety) grown in the greenhouse at the USDA-ARS in Byron, GA. The treatments were terminated 8 weeks post-inoculation and measurements of the plants were conducted as well as quantification of the root-knot nematode populations. The treatments included ten individual plants each split over two trials. The metabolite treatments appear to have had an impact on the tomato plants and nematode populations. Metabolite treatments had lower quantities of nematodes and eggs than the nematode control and more than the broth-only control. Plant growth parameters were lower in the nematode control, and the metabolite treatments had similar values to those of the broth-only control. There are potentially beneficial effects of the metabolites to plant growth over the broth-only control, but more tests are required to determine if this effect is real. We also evaluated the efficacy of application timing \5 days before planting (DBP) and at plant (AP)\ of two bacterial metabolites, Xenorhabdus szentirmaii and X. bovienii, against the root-knot nematode Meloidogyne incognita on cabbage in two environmental conditions (screenhouse and greenhouse) at the University of Georgia, Tifton campus, GA. At transplant, recommended applications of Paecilomyces lilacinusstrain 251 (MeloCon WG) and secondary metabolites of Burkholderia rinojensisstrain A396 (Majestene) were also included in the trials for comparison. Plants were infected with 2,500 M. incognita second-stage juveniles (J2), soil-drenched with the metabolites or nematicides, and grown for 450-degree days using a base temperature of 10 °C to complete two generations. Plants treated with water were considered the untreated check, and each treatment had six replications arranged in a completely randomized design. In the greenhouse, the X.szentirmaii metabolite at 5 DBP had a lower (P< 0.05) root gall rating than the control. Both metabolites had significantly lower root galling compared to Majestene, MeloCon, and control treatments. The metabolites reduced M. incognita egg counts per gram of root compared to other treatments in the greenhouse; however, there were no differences in the egg count between the metabolites. In the screenhouse, the AP application of X.szentirmaii and X. bovienii at 5 DBP reduced the egg count compared to Majestene and the control; however, no differences in the egg counts between the metabolites were observed. Suppressive effects of winter cover crops on root-knot nematode populations in the field conditions. Two independent trials were conducted in winter 2021 and 2022 in a field naturally infested with the root-knot nematode (RKN; Meloidogyne incognita) to determine the effect of different termination timing of cover crops on nematode development in South Georgia, USA. The study utilized a randomized complete block design with five treatments \oilseed radish (cv. Carwoodi), oat (Tachibuki), rye (Wrens Abruzzi), mustard (Caliente), and rye-oat mixture\. Two fallows (with and without weeds) were included as controls. Each plot was 5 ft wide and 25 ft long with 6 ft between them. The cover crops were planted in early October and terminated 90 and 120 days after planting. Cover crop residues were then incorporated into the soil by a moldboard plow to achieve a maximum volume of allelopathic and/or nematicidal activity. RKN population densities were examined before planting, at termination, and two weeks after incorporating the crop residue into the soil. Biomass accumulation was determined using 10 random representative plants at the termination of cover crops. Oven-dried aboveground parts of plants were weighed, and their root systems were assessed for RKN gall severity. The RKN abundance differed significantly between the two years (2021 and 2022). In 2021, there was an increase in the nematode population (P < 0.05) when the cover crops were left longer (120 days) in the field compared to a shorter period (90 days). The incorporation of cover crops in the soil was not significant in terms of RKN abundance in both trials. In 2021, rye-oat had the lowest RKN abundance compared to other treatments, while radish had the highest abundance. There were no significant differences in the nematode density between rye, mustard, and the two fallows. In 2022, RKN abundance was not significantly affected by either the termination period (90 and 120 days) or cover crop incorporation in the soil. However, there were differences among the treatments with the fallow with weeds having the highest RKN abundance (P < 0.01) compared to other treatments. Oat, rye, and fallow without weeds had the lowest RKN abundance. The cover crop biomass was significantly higher in 2021 than in 2022, with radish having the highest biomass. Mustard had a higher galling index (P < 0.01) than other cover crops in both 90 and 120 termination days, while oat, rye and rye-oat mixture had the lowest galling index. In conclusion, rye and rye-oat mixture can reduce M. incognita populations in the soil. Additionally, leaving cover crops in the field for a longer period can lead to nematode population build-up that would negatively impact consecutive cash crops. **Publications** - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Marquez, J., and Hajihassani, A. Pyramiding cover crop rotation of sunn hemp or rye with tillage practices for suppression of nematodes, fungal soil-borne diseases, and weeds in a bare-ground vegetable production system. 66th Annual Conference on Soilborne Plant Pathogens and the 51st Annual Statewide California Nematology Workshop, March 23-24, 2021. - Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Gitonga, D., Hamidi, N., and A. Hajihassani, A. 2021. Efficacy of certified bionematicides for control of Meloidogyne incognita in the greenhouse conditions. Journal of Nematology 53: 11. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Hajihassani, A., Timper, P., and Shapiro-Ilan, D. 2022. Effects of application timing on the efficacy of Xenorhabdus metabolites for control of Meloidogyne incognita. The 7th International Congress of Nematology, 1-6 May 2022, Antibes Juan-Les-Pins, France. Progress 09/01/20 to 04/04/22 Outputs Target Audience:This project has diverse audiences of growers, cooperative extension personnel, scientific community, crop consultants and professionals, and industry cooperators. Changes/Problems:The PI of this project, Dr. Abolfazl Hajihassani, left the University of Georgia in January 2022 to start a new nematology program at the University of Florida (UF) Fort Lauderdale Research and Education Center. The PI is currently working with USDA-NIFA on the possibility of transferring the grant to UF and modifying objectives to continue completing the project. Due to this fact, we will need to request USDA-NIFA for a six-month to one-year No-Cost Extension to be able to complete the project. What opportunities for training and professional development has the project provided?A Ph.D. student (Denis Gitonga) was hired from the proposal and is currently working on the project at the University of Georgia. This student will be transferred to the University of Florida (UF) in May 2022 to continue working on this project's objectives. In addition, a temporary technician will be hired at the UF to assist in the completion of this project. Three research technicians/biologists were able to assist in the preparation of Bt cry isolates and EPN metabolites at the UMass Medical School and USDA-ARS, Byron, GA, respectively. How have the results been disseminated to communities of interest?The greenhouse results on the efficacy of bionematicide products in the control of root-knot nematodes were presented as a poster at the annual meeting of the Society of Nematologists in Alabama in the summer of 2021. Data from greenhouse studies were also presented at the Southeast Regional Fruit and Vegetable Conference on January 7, 2022, in Savannah, GA. In addition, a training workshop \"Cover crop production and soil health\" was established on July 6, 2021, and the preliminary results from the cover crop study were shared with 21 extension agents from Georgia. What do you plan to do during the next reporting period to accomplish the goals?Complete nematode bioassays, conduct the economics analysis, prepare manuscripts, and present the results at appropriate scientific or extension meetings. Impacts What was accomplished under these goals? We evaluated the efficacy of application timing \5 days before planting (DBP) and at plant (AP)\ of two bacterial metabolites, Xenorhabdus szentirmaiiandX. bovienii, against the root-knot nematode Meloidogyne incognita on cabbage in two environmental conditions (screenhouse and greenhouse) at the University of Georgia (UGA), Tifton campus, GA. At transplant, recommended applications of Paecilomyces lilacinusstrain 251 (MeloCon WG) and secondary metabolites of Burkholderia rinojensis strain A396 (Majestene) were also included in the trials for comparison. Plants were infected with 2,500 M. incognita second-stage juveniles (J2), soil-drenched with the metabolites or nematicides, and grown for 450 degree days using a base temperature of 10 °C to complete two generations. Plants treated with water were considered the untreated check, and each treatment had six replications arranged in a completely randomized design. In the greenhouse, the X.szentirmaii metabolite at 5 DBP had a lower (P< 0.05) root gall rating than the control. Both metabolites had significantly lower root galling compared to Majestene, MeloCon, and control treatments. The metabolites reduced (P< 0.05)M. incognitaegg counts per gram of root compared to other treatments in the greenhouse; however, there were no differences in the egg count between the metabolites. In the screenhouse, the AP application of X.szentirmaii and X. bovieniiat 5 DBP reduced the egg count compared to Majestene and the control; however, no differences in the egg counts between the metabolites were observed. Two independent greenhouse experiments were conducted at the UGA Tifton campus, GA to evaluate the nematicidal efficacy of eight commercially available products (Majestene, TerraNeem, AzaGuard, Molt-X, NemOmex, EcoWorks, Monterey, and Promax) against Meloidogyne incognita. After eight weeks, shoot length, shoot dry weight, fresh root weight, root gall severity using a scale of 0 to 5, and reproduction factor (Pf/Pi) were evaluated. There was no significant difference in the dry shoot weight and shoot length among all the treatments. AzaGuard and Majestene had the highest (P < 0.05) root weight, while Monterey had the lowest root weight compared to both control checks. Monterey had the lowest (P < 0.05) galling index, followed by AzaGuard and Molt-X compared to the positive control. However, Monterey had undesirable effects on the root system resulting in low galling severity and egg counts. The number of eggs per gram of root at the end of the experiments varied greatly and ranged from 1806 to 4815. Azaguard had the lowest (P < 0.05), while TerraNeem had the highest eggs per gram of roots compared to the positive control. AzaGuard outperformed all the other bionematicides and was selected along with a few other potential products for the field trials to manage Meloidogyne spp. in organic vegetables. A field study was conducted using cucumber in a certified organic field naturally infested with Meloidogyne spp., at the UGA Horticulture Hill Farms, Tifton, GA in April 2021. The trial utilized a randomized complete block design with seven treatments and five replicates. The experimental treatments used were: untreated control, AzaGuard, NemOmex, EcoWorks, Pendi, and Promax. RKN population was not significantly (P = 0.0933) affected by nematicide application. Despite a lack of statistically significant RKN reduction, Azaguard and Ecoworks were the best compared to other products. The root galling was significantly less treated with Azaguard compared to other products including the untreated check. On the other hand, Pendi showed a significantly high galling index compared to other products but with control. Neither of the biological nematicides significantly (P=0.5806) affected the cucumber yield. However, numerically Ecoworks performed better compared to other treatments and the untreated check. Overall, the best two products were Ecoworks and Azaguard while the worst two were; Promax and Nemomex. This trial was repeated in July 2021, but the data were not included in this report due to time constraints. Another study was conducted in a certified organic field naturally infested with Meloidogyne spp., at the UGA Horticulture Hill Farms, Tifton, GA to determine the effect of different termination timing of cover crops on the development and population of nematodes and weed density. Winter cover crops were grown in the field in early November 2020 and terminated (harvested) 90 and 120 days after planting. Cover crop residues were then incorporated into the soil by a moldboard plow to achieve maximum allelopathic and/or nematicidal activity. Two weeks after incorporation, planting beds (false seedbeds) were prepared to stimulate weeds to germinate. Data collected included cover crop biomass accumulation, the abundance of plant-parasitic nematodes, root galling severity, and weed density. A significant difference (P = 0.0116) in RKN populations was found between the interaction effects (Days in the field \"90 & 120\" and the cover crops) when analyzed using a two-way ANOVA. There was a significant (P = 0.0436) increase in RKN population when the cover crops were left longer (120 days) in the field compared to a shorter period (90 days), especially for radish. There were no significant differences found between the interaction effects (before and after) cover crop incorporation in the soil trials (90 and 120 cover crops. When pooling and analyzing the data from the two trial periods using a one-way ANOVA, significant differences were found among the treatments. Further analysis using Tukey HSD test, Rye-Oat had the lowest RKN population compared to other cover crops while Radish (P = 0.0006) had the highest population of RKN. Rye, Mustard, and Oat did not differ significantly from one another, and neither were any significant differences between the three treatments and the fallow (with weeds and without weeds). No significant difference in free-living nematode populations was found between the interaction effects (Days in the field \"90 & 120\" and the cover crops) when analyzed using a two-way ANOVA. Once pooling and analyzing the data from the two trial periods using a one-way ANOVA, significant differences (F = 4.8002; P = 0.0304) were found between 90 and 120 days. Generally, 90 days had more free-living nematodes compared to 120 days. There was a significant difference (F = 2.5793; P = 0.022) between the before and after incorporation of cover crops. Amongst all the cover crops, Rye, Radish and Mustard had a significant increase in the number of free-living nematodes after incorporation into the soil compared to before incorporation. No significant difference in cover crop biomass was found between the interaction effects (Days in the field \"90 & 120\" and the cover crops) when analyzed using a two-way ANOVA. When pooling and analyzing the data from the two trial periods using a one-way ANOVA, also no significant differences were detected between 90 and 120 days. However, there was a significant difference (P = 0.0027) between the cover crops. Radish had significantly higher (P=0.0049) biomass compared to other cover crops, while Rye (P=0.0449) and Mustard (P=0.0056) had the lowest biomass, respectively. The most prominent weeds that were identified were cut-leaf primrose and corn spurry. Other weeds identified include cut leaf geranium, sedge, datilograss, and pigweed. The weeds data is under analysis. The second repeat of the cover crop study using the same treatments was established at the University of Georgia, Tifton campus in November 2021, and completed in April 2022. Data from the 2-year cover crop study will be analyzed and reported. In addition, UMass has prepared several Bt isolates for establishing the laboratory bioassays to evaluate their nematicidal effectiveness against the root-knot nematode. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2021 Citation: Gitonga, D., Hamidi, N., and A. Hajihassani, A. 2021. Efficacy of certified bionematicides for control of Meloidogyne incognita in the greenhouse conditions. Journal of Nematology 53: 11. . Progress 09/01/20 to 08/31/21 Outputs Target Audience:The target audience for this project isExtension agents and growers in Georgia and the neighboring states. However, the results will be used by extension specialists, county extension agents, crop consultants and professionals, and industry cooperators. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?A Ph.D. student (Denis Gitonga) was hired from the proposal and is currently working on the project at the University of Georgia. In addition, three research technicians/biologists were able to assist in the preparation of Bt cry isolates and EPN metabolites at the UMass Medical School and USDA-ARS, Byron, GA, respectively. How have the results been disseminated to communities of interest?The greenhouse results on the efficacy of bionematicide products in the control of root-knot nematodes were presented as a poster at the annual meeting of the Society of Nematologists in Alabama in summer 2021. In addition, we plan to share the results with Extension agents and growers this winter at the 2022 Southeast Regional Fruit and Vegetable Conference in Savannah, GA, and at county grower meetings in GA. What do you plan to do during the next reporting period to accomplish the goals?Start or repeat studies to complete objectives 1 to 3, begin economics analysis, prepare manuscripts, and hopefully present studies at appropriate meetings.? Impacts What was accomplished under these goals? Two independent greenhouse experiments were conducted to evaluate the nematicidal efficacy of eight commercially available products (Majestene, TerraNeem, AzaGuard, Molt-X, NemOmex, EcoWorks, Monterey, and Promax) against root-knot nematode (RKN), Meloidogyne incognita. After eight weeks, shoot length, shoot dry weight, fresh root weight, root gall severity using a scale of 0 to 5, and reproduction factor (Pf/Pi) were evaluated. There was no significant difference in the dry shoot weight and shoot length among all the treatments. AzaGuard and Majestene had the highest (P < 0.05) root weight, while Monterey had the lowest root weight compared to both control checks. Monterey had the lowest (P < 0.05) galling index, followed by AzaGuard and Molt-X compared to the positive control. However, Monterey had undesirable effects on the root system resulting in low galling severity and egg counts. The number of eggs per gram of root at the end of the experiments varied greatly and ranged from 1806 to 4815. Azaguard had the lowest (P < 0.05), while TerraNeem had the highest eggs per gram of roots compared to the positive control. AzaGuard outperformed all the other bio-nematicides and was selected along with a few other potential products for the field trials to manage Meloidogyne spp. in organic vegetables. 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However, numerically Ecoworks performed better compared to other treatments and the untreated check. Overall, the best two products were Ecoworks and Azaguard while the worst two were; Promax and Nemomex. This trial was repeated in July 2021, but the data were not included in this report due to time constraints. Another study was conducted in a certified organic field naturally infested with Meloidogyne spp., at the UGA Horticulture Hill Farms, Tifton, GA to determine the effect of different termination timing of cover crops on the development and population of nematodes and weed density. Winter cover crops were grown in the field in early November 2020 and terminated (harvested) 90 and 120 days after planting. Cover crop residues were then incorporated into the soil by a moldboard plow to achieve maximum allelopathic and/or nematicidal activity. Two weeks after incorporation, planting beds (false seedbeds) were prepared to stimulate weeds to germinate. Data collected included cover crop biomass accumulation, the abundance of plant-parasitic nematodes, root galling severity, and weed density. A significant difference (F = 2.885; P = 0.0116) in RKN populations was found between the interaction effects (Days in the field \"90 & 120\" and the cover crops) when analyzed using a two-way ANOVA. There was a significant (F = 4.1584; P = 0.0436) increase in RKN population when the cover crops were left longer (120 days) in the field compared to a shorter period (90 days), especially for radish. There were no significant differences (F = 0.4303; P = 0.8575) found between the interaction effects (before and after) cover crop incorporation in the soil trials (90 and 120 cover crops. When pooling and analyzing the data from the two trial periods using a one-way ANOVA, significant differences (F = 3.6971; P = 0.0021) were found among the treatments. Further analysis using the Tukey HSD test, Rye-Oat (P = 0.0062) had the lowest RKN population compared to other cover crops while Radish (P = 0.0006) had the highest population of RKN. Rye, Mustard and Oat did not differ significantly from one another, and neither were any significant differences between the three treatments and the fallow (with weeds and without weeds). No significant difference (F = 0.4835; P = 0.08196) in free-living nematode populations was found between the interaction effects (Days in the field \"90 & 120\" and the cover crops) when analyzed using a two-way ANOVA. Once pooling and analyzing the data from the two trial periods using a one-way ANOVA, significant differences (F = 4.8002; P = 0.0304) were found between 90 and 120 days. Generally, 90 days had more free-living nematodes compared to 120 days. There was a significant difference (F = 2.5793; P = 0.022) between the before and after incorporation of cover crops and the cover crops. Amongst all the cover crops, Rye, Radish and Mustard had a significant increase in the number of free-living nematodes after incorporation in the soil compared to before incorporation. No significant difference (F = 0.2428; P = 0.9123) in cover crop biomass was found between the interaction effects (Days in the field \"90 & 120\" and the cover crops) when analyzed using a two-way ANOVA. When pooling and analyzing the data from the two trial periods using a one-way ANOVA, also no significant differences (F = 2.8801; P = 0.0975) were detected between 90 and 120 days. However, there was significance difference (F = 4.8831; P = 0.0027) between the cover crops. Radish had significantly higher (P=0.0049) biomass compared to other cover crops, while Rye (P=0.0449) and Mustard (P=0.0056) had the lowest biomass, respectively. The most prominent weeds that were identified were cut-leaf primrose and corn spurry. Other weeds identified include cut leaf geranium, sedge, datilograss, and pigweed. The weeds data is under analysis. Publications

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Soil Health and Management in Organic Systems: Identifying Meaningful Targets and Pathways Towards Resilience

Accession No.	1023737
Project No.	IDA02006-CG
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Performing Institution	UNIV OF IDAHO, 875 PERIMETER DRIVE, MOSCOW, IDAHO 83844-9803

NON-TECHNICAL SUMMARY

Organic farming systems rely on biologically mediated processes to provide plants with essential nutrients and to suppress pests. This reliance is central to the soil health concept, but surprisingly little soil health research has been conducted in certified organic systems. Organic growers face additional challenges associated with the need for mechanical tillage, which is known to decrease soil organic carbon and aggregation and increase soil erosion, to control weeds. Growers need science-based training to build soil health using organic-approved management options. To address this need we bring together research and extension scientists, experienced in soil ecology and soil health, to deliver relevant information to help growers manage for soil health and productivity. We provide tools and targets to guide soil management during the transition to organic, thereby increasing soil health and function of organic systems. The specific goal of this project is to is to facilitate the development of resilient certified organic farming systems in Idaho and eastern Washington through enhanced knowledge of the impacts of tillage management and organic amendments on soil biological communities and soil health, and to use this knowledge to create meaningful soil health targets and pathways to success for transitioning farmers. Specific and interrelated research (R) and extension (E) objectives that directly relate to key barriers to successful transition to organic production were developed to achieve this goal. They include:R1) Assess the interaction between tillage and organic inputs and how these practices impact soil health indicators and yields in transitional systems located in two different climatic zones.R2) Use population and community structures of nematodes, arthropods, and earthworms to assess changes in soil health under three different management strategies during the transition to organic certification, with special focus on key pest and beneficial species.R3) Assess a suite of soil health indicators to determine how they can be used to predict management and yield potential in differently aged organic certified systems.RE4) Develop, in collaboration with farmers, meaningful soil health targets based on knowledge of how indicators vary over time and space in two climatic zones.E5) Utilize existing farmer networks to create regional learning communities for sharing best practices and soil health successes.E6) Increase knowledge of soil health, soil testing, and conservation tillage options through dissemination of project results.

OBJECTIVES

The overall goal of this project is to facilitate the development of resilient certified organic farming systems in Idaho and eastern Washington through enhanced knowledge of the impacts of tillage management and organic amendments on soil biological communities and soil health, and to use this knowledge to create meaningful soil health targets and pathways to success for transitioning farmers.Specific Objectives include:1) Assess the interaction between tillage and organic inputs and how these practices impact soil health indicators and yields in transitional systems located in two different climatic zones.2) Use population and community structures of nematodes, arthropods, and earthworms to assess changes in soil health under three different management strategies during the transition to organic certification, with special focus on key pest and beneficial species.3) Assess a suite of soil health indicators to determine how they can be used to predict management and yield potential in differently aged organic certified systems.4) Develop, in collaboration with farmers, meaningful soil health targets based on knowledge of how indicators vary over time and space in two climatic zones.5) Utilize existing farmer networks to create regional learning communities for sharing best practices and soil health successes.6) Increase knowledge of soil health, soil testing, and conservation tillage options through dissemination of project results.

APPROACH

The general research methods used during this project are summarized for each component of the project below.Soil health research: Experimental plots (randomized complete block design) will be developed at four sites (two in each climatic zone) to determine the relationship between tillage disturbance and organic inputs. Three disturbance levels, quantified by the STIR values, and three levels of organic amendments will be utilized. Soil health indicators, including soil fauna, will be analyzed each year according to standard and accepted procedures. In additional fields, soil health indicators will be measured each year to determine changes in relation to management and weather. Each data set will be analyzed using standard (uni-and multi-variate) statistical techniques. The goal of statistical analyses will be to 1) determine the ability of organic amendments to ameliorate negative impacts caused by tillage disturbance, 2) determine annual and spatial variability in soil health indicators within and across climatic zones, 2) determine relationships between soil health indicators and yield potentials, 3) determine management impacts on soil health indicators, and 4) identify trends in soil health indicators as sites are transitioned to organic status. Data will be reported and disseminated widely through research presentations to regional, national and international audiences and high quality publications.Extension: Learning communities will be established to better connect organic farmers and organic farmers and researchers. Annual meetings will be established and serve as an opportunity for sharing among farmers and between farmers and researchers. Farm tours and virtual field days will be utilized as ways of demonstrating and increasing knowledge of the management practices that build soil health. Extension workshops will be utilized as a forum to share data and collectively identify the most meaningful and practical soil health indicators for each of the climatic zones. Findings will be disseminated through several extension-type products including websites, fact-sheets and videos.Overall project evaluation: Project evaluation will involve post-workshop/farm tour evaluation surveys, a mid-term outcomes survey, and annual team evaluation surveys. The post-workshop and farm tour surveys will evaluate learning, anticipated behavior changes, and the content and quality of the educational experience (i.e., short-term outcomes) in years 1-3 of the project. We will collect workshop and farm tour evaluation data in person through paper surveys at each event. Gathering evaluation data in person at events will ensure a high participation rate. We will enter paper survey results into a spreadsheet for ease of data management and analysis. The results of these surveys will be used to formatively evaluate, modify, and improve the workshops throughout the project and afterward. In year 3, we will conduct a mail survey of the previous workshop and farm tour participants to document and evaluate their implementation of specific mid-term changes in behavior and conditions resulting from program participation. Progress 09/01/20 to 08/31/24 Outputs Target Audience:The target audience for this project includes the following groups: 1. Agronomists, soil scientists, and entomologists at other research institutions and within USDA 2. Extension educators from Idaho and other states where organic farming is of interest 3. Organic farmers and farmers interested in transitioning to organic production 4. Other stakeholders from across the food system. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?This project has provided experience and training in field sampling, experimental design, data analysis, laboratory analysis of soil and plant samples for two graduate students and five undergraduates. All project participants have learned more about other fields (soil science, agronomy, entomology and project evaluation). How have the results been disseminated to communities of interest?Project results have been disseminated through multiple pathways. Regional workshops provided an opportunity to provide information regarding project goals and soil health concepts to a large group of farmers and other food-system stakeholders. Abstracts have been submitted and accepted for presentations at national level scientific meetings. One thesis has been published. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Objective 1: Major activities: Replicated plots in both southern (Magic Valley) and northern Idaho (Palouse region) to determine differential impacts of tillage disturbance and organic inputs (compost). All tillage/soil management practices were recorded to determine disturbance level. Three levels of disturbance were created and either organic (compost) or processed organic fertilizers were added. In the Palouse region, alfalfa was taken out in the fall of 2023 after the last alfalfa harvest while alfalfa was taken out in the Magic Valley in the Spring 2024. For both regions, the three levels of disturbance was maintained during alfalfa termination. Plots were seeded to feed barley in the spring of 2024. Weeds were managed throughout season, and crop was harvested. Data Collected: Soil health sampling (chemical, physical, and biological indicators) was conducted. Weed, alfalfa and barley crop biomass were sampled. Data Summary/Discussion: In the Palouse, upon harvest, total above ground biomass of spring barley was nearly double at Colfax (424.7g/m\^2) compared to Soil Stewards farm (225.50 g/m\^2). Across both sites, higher barley yield was associated with higher tillage and the previous year\'s crop volunteers were nonexistent in the high tillage treatments. Weed presence depended on location. At Soil Stewards, weed biomass was highest at sites with low tillage (109.33 g/m\^2), while at Colfax, weed biomass was highest at sites with high tillage (82.83 g/m\^2). POXC averaged higher at Colfax plots (833.19 mg/kg soil) when compared to Soil Stewards plots (452.95 mg/kg soil). POXC decreased with depth across both sites. There were no consistent trends for tillage or fertilizer across both sites. Treatment effects of tillage and fertilizer application depended on location. For example, Colfax plots had an inverse relationship of POXC levels and increasing tillage regardless of depth. This trend was consistent at Soil Stewards at 30 cm depth. However, at depths of 10 and 20 cm, higher levels of POXC were associated with higher levels of tillage. In addition, Colfax plots had higher POXC at sites with fertilizer across depth, whereas POXC levels were lowest among fertilizer treatments at depths 20 and 30 cm at Soil Stewards. Organic Matter was double at Colfax (5.8 %), compared to Soil Stewards (2.5 %). No notable differences were found between tillage treatments at Soil Stewards. Colfax trended towards higher levels of organic matter under low tillage. Organic matter was not impacted by soil amendments within sites. Average Bray-P levels were higher at Colfax (243.5 ppm) when compared to Soil Stewards (173.2 ppm. Across tillage treatments at Grey Duck Farms, Bray-P levels trended higher in low tillage treatments. In comparing soil amendments, Bray-P was higher in plots with a double rate of compost. Inorganic N levels were slightly higher at Colfax (7.5 mg N/kg soil) when compared to Soil Stewards (5.1 mg N/kg soil). Across both sites, higher tillage generally correlated with higher levels of N. However, soil amendment effects were inconsistent across sites. In the Magic Valley region, spring barley yields were higher than those in the Palouse. At the Twin Falls site, barley yield averaged 543.8 g/m\^2 while yields at Kimberly averaged 852.4 g/m\^2. Volunteer alfalfa was higher at the Twin Falls site compared to Kimberly and was also higher in lower tillage intensities. Weeds were only present at the Twin Falls site and were present in only two plots. Additionally, barley yields were highest in the highest intensity tillage, followed by the lowest tillage intensity, and medium tillage intensity having the lowest barley yields. Yields were highest in the plots with the highestcompost applications and followed by the processed organic fertilizer plots. POxC was substantially lower in Southern Idaho than in Northern Idaho; the Kimberly plots averaged 331.46 mg/kg soil while the Twin Falls plots averaged 404.35 mg/kg soil. POxC decreased with depth across both Southern Idaho sites. Unlike Northern Idaho, POxC increased with decreasing tillage intensity at both sites in Southern Idaho. Across both sites, POxC averaged 390.17 mg/kg soil in the lowest tillage intensity, 372.68 mg/kg soil for medium tillage intensity, and 340.87 mg/kg soil in the highest tillage intensity. There was no consistency in the effective of organic matter addition on POxC between the two sites, however. Total organic carbon was over twice the amount in Twin Falls (0.94%) compared to the plots in Kimberly (0.44%) and TOC decreased with increasing depth. For both sites, increasing tillage intensity decreased TOC content (0.76%, 0.69%, and 0.62% for low, medium, and high tillage intensities, respectively). For both sites, the double compost rate had the highest TOC content (0.75%) but the other two treatments were not consistent between sites. Olsen P and inorganic N were greater at the Twin Falls site (20.0 ppm and 13.1 ppm, respectively) compared to the Kimberly site (21.7 ppm and 19.6 ppm, respectively). Olsen P nor inorganic N does not appear to be impacted by tillage intensity but for both metrics the double rate of compost had the highest concentrations. Data from 2024 are still being analyzed in order to find significant differences in soil health indicators based on differing tillage and organic amendment treatments.Outcomes: Four years of cumulative impacts of tillage with different levels of organic amendments on spring barley biomass and first year growth have been demonstrated in two different climate/growing zones. Objective 2: Major activities: Earthworms, nematodes, and arthropods were sampled at each site described in objective 1. Data Summary/Discussion: For the Palouse, all adult earthworms found in 2024 were Aporrectodea trapezoides. Grey Duck Farms averaged 137 individuals m-2, and Soil Stewards averaged 37 individuals m-2. Across both sites, low tillage trended towards the highest population densities (141 individuals m-2), while medium tillage trended towards the lowest densities(43 individuals m-2). Soil amendment trends were not consistent across sites: double rate compost at the Grey Duck Farms site trended towards the highest densities within that site, whereas at Soil Stewards double rate compost trended towards the lowest densities. For the Magic Valley, Kimberly averaged 164 individuals m-2, and Twin Falls averaged 54 individuals m-2. Across both sites, medium tillage trended towards the highest population densities (173 individuals m-2), while high tillage trended towards the lowest densities (26 individuals m-2). Soil amendment trends were not consistent across sites: double rate compost at the Kimberly site trended towards the highest densities within that site, whereas at Twin Falls double rate compost trended towards the lowest. Objective 3: Not in year 4. Objective 4: Major activities: Samples collected in the project have been analyzed or are being analyzed for a wide range of soil health indicators. Data Summary/Discussion: Statistical analyses of the completed soil health indicators for all years are underway and will be reviewed by project PIs and stakeholders soon. Objective 5: Major activities: Stakeholders have been identified and have received project communications. A discussion and forum was held in January 2024 in Twin Falls. Data Summary/Discussion: Regional meetings were held at several outreach events. Objective 6: Major activities: Results of this project have been disseminated through the 2023 and 2024 meeting and scientific meetings. Presentations/Publications: Oral presentations were given at the University of Idaho Small Farms Round Table talk series in Moscow, Idaho, the 2023 Impromptu Kimberly Field Tour, 2024 KREC Weed Tour in Kimberly, Idaho, and at the Magic Valley Soil Health Forum in Twin Falls. Data was also incorporated into an oral presentation at the ASABE Annual International Meeting in Anaheim, CA in July. Publications Type: Theses/Dissertations Status: Published Year Published: 2023 Citation: Temmen, D. Maximizing Soil Health on Small-Scale Organic Farms in the Inland Pacific Northwest. December 2023. Thesis. University of Idaho. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Schott, L., J. Yost, A. Agin, D. Olsen, A. Leytem, R. Dungan, A. Moore, C. Cosdon, J. Jamison, K. Kruger, E. Brooks, and H. Salem. When Soil Carbon isnt Everything: Impact of Regenerative Practices on Soil Health Practices on Soil Health Metrics in the Semi-Arid West. 2024 ASABE Annual International Meeting. 30 July 2024. Anaheim, CA (oral presentation). Progress 09/01/22 to 08/31/23 Outputs Target Audience:The target audience for this project includes the following groups: 1. Agronomists, soil scientists, and entomologists at other research institutions and within USDA 2. Extension educators from Idaho and other states where organic farming is of interest 3. Organic farmers and farmers interested in transitioning to organic production 4. Other stakeholders from across the food system. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Objective 1. Major activities: Replicated plots in both southern (Magic Valley) and northern Idaho (Palouse region) developed in 2021 to determine differential impacts of tillage disturbance and organic inputs (compost) were monitored. All tillage/soil management practices were recorded to determine disturbance level. Three levels of disturbance were created and either organic (compost) or processed organic fertilizers were added. Plots were seeded to alfalfa (AL) and orchardgrass (OG) mixtures. Weeds were managed throughout season, and crop was harvested. Data Collected: Soil health sampling (chemical, physical, and biological indicators) was conducted. Germination/emergence of AL and OG were measured. Weed and crop biomass were sampled. The sites were sampled once per year with either 3 (nematodes) or 9 (microarthropods) samples per site. Data Summary/Discussion: Across the total 150 cm subsampled rows, AL germination at Palouse sites ranged from 5 to 50 seedlings, and OG germination ranged from 124 to 307 seedlings, with higher germination rates at Grey Duck Farm compared to Soil Stewards Farm. Upon harvest, weed biomass, alfalfa biomass, and orchardgrass biomass was higher at Grey Duck Farm compared to Soil Stewards farm; alfalfa biomass ranged from 21.3 to 89.8 g, orchardgrass biomass ranged from 5.6 to 67.4 g, and weed biomass ranged from 202.4 to 651.8 g. Across the two farms, infiltration rates ranged from 0.86 to 600 cm/hr, and bulk density ranged from 0.71 to 1.51 g/cm3 . Data from 2022 are still being analyzed in order to find significant differences in soil health indicators based on differing tillage and organic amendment treatments. Approximately 3,000 nematodes and arthropods have been processed and are currently being identified. Outcomes: Impacts of tillage with different levels of organic amendments on AL/OG establishment and first year growth have been demonstrated in two different climate/growing zones. Objective 2. Major activities: Earthworms, nematodes and arthropods were sampled at each of the plots described in objective 1. Data Collected: Earthworms biomass and density were measured. Earthworms were identified to the species level in the lab. In each plot, 9 nematode samples and 9 arthropod samples were collected. Data Summary/Discussion: Earthworm density ranged from 16 to 480 individuals/m2. Earthworm biomass ranged from 0 to 398 g/m2. Three species (all exotic) of earthworms were identified: Aporrectodea tuberculate, Aporrectodea trapezoides, and Lumbricus terrestris. Nematodes and arthropods collected in 2022 are still being identified. Approximately 9,000 nematodes are arthropods have been processed from these samples and are currently being identified. Outcomes: This data set represents the first statewide assessment of soil macro and mesfauna in organic systems in Idaho. When completed the data set will allow us to better understand the relationship between these organisms and soil health and management. Objective 3. Major activities: Soil was sampled along the 3 transects at each of the 10 sites (5 in the Palouse and 5 in the Magic Valley) established in 2021..Data Collected: Chemical, biological, and physical indicators of soil health were analyzed. Arthropods and nematodes were sampled. Data Summary/Discussion: Across the five sites in the Palouse, physical soil measurements showed that bulk density ranged from 0.63 to 1.48 g/cm3 and the water infiltration rate ranged from 1.65 to 85.7 cm/hr. Soil pH ranged from 5 to 7.5, the soil organic matter ranged from 1.8 to 9.6%. The Haney soil health score ranged from 4.5 to 32.9 across the five farms. Additionally, available N ranged from 4.9 to 50.9 mg/kg, the available P from 6.2 to 594.4 mg/kg, and the available K from 14.0 to 545.0

mg/kg. In terms of biological indicators, the microbial active Publications Type: Journal Articles Status: Published Year Published: 2022 Citation: White, P.T., K.J. Wolf, J. Johnson-Maynard. 2022. Changes in teacher attitudes relating to climate science. Natural Sciences Education https://doi.org/10.1002/nse2.20086 Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Johnson-Maynard, J. Crop Diversification and Soil Health in Dryland Wheat-Based Agroecosystems in the Inland Pacific Northwest USA. World Congress of Soil Science. Glasgow, Scotland, July 31-Aug 5, 2022 Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Kahl, K., E. Brooks, J. Johnson-Maynard. Impacts of fallow replacement crops on nitrogen and water use efficiency in dryland wheat cropping systems, Pacific Northwest, USA. World Congress of Soil Science. Glasgow, Scotland. Aug. 2, 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: S. Baskota, J. Johnson-Maynard, C. Seavert and Kurtis Schroeder. Diversification of Wheat-Based Cropping Systems in the Inland Pacific Northwest with Alternative Crops. Annual Meeting of the Soil Science Society of America, Baltimore, Maryland; Nov. 6-9, 2022. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:The target audience for this project includes the following groups: Agronomists, soil scientists, and entomologists at other research institutions and within USDA Extension educators from Idaho and other states where organic farming is of interest Organic farmers and farmers interested in transitioning to organic production Other stakeholders from across the food system. Changes/Problems: As reported in 2021, extreme heat and dry conditions resulted in failed stands in northern Idaho. These plots were reseeded in 2022 and growth was good. For this reason, the alfafa/orchardgrass phase will be extended for an additional year in both the Palouse and Magic Valley regions. The crop will be taken out in 2023 and barley planted and monitored. A one-year-no-cost-extension will be requested to complete the work. What opportunities for training and professional development has the project provided? This project has provided experience and training in field sampling, experimental design, data analysis, laboratory analysis of soil and plant samples for two graduate students and one undergraduate. All project participants have learned more about other fields (soil science, agronomy, entomology and project evaluation). How have the results been disseminated to communities of interest? Project results have been disseminated through multiple pathways. The Organic Workshop provided an opportunity to provide information regarding project goals and soil health concepts to a large group of farmers and other food-system stakeholders. Abstracts have been submitted and accepted for presentations at national level scientific meetings. Future workshops have been scheduled for Dec. 1, 2022 and late Feb. 2023. What do you plan to do during the next reporting period to accomplish the goals? Soil health, earthworms, nematodes and arthropods will continue to be monitored in replicated plots utilized for testing disturbance and organic matter input treatments. Alfalfa yield will be monitored. The time-series transects at all 10 sites will be sampled in the spring for chemical, physical and biological soil health indicators. Stakeholders will be gathered forproject meetings andproject data will be disseminated at meetings and conferences. Survey instruments will be disseminated andproducer evaluation data will be collected. **Impacts** What was accomplished under these goals? Objective 1. Major activities: Replicated plots in both southern (Magic Valley) and northern Idaho (Palouse region) developed in 2021to determine differential impacts of tillage disturbance and organic inputs (compost) were monitored. All tillage/soil management practices were recorded to determine disturbance level. Three levels of disturbance were created and either organic (compost) or processed organic fertilizers were added. Plots were seeded to alfalfa (AL) and orchardgrass (OG) mixtures. Weeds were managed throughout season, and crop was harvested. Data Collected: Soil health sampling (chemical, physical, and biological indicators) was conducted. Germination/emergence of AL and OG were measured. Weed and crop biomass were sampled. The sites were sampled once per year with either 3 (nematodes) or 9 (microarthropods) samples per site. Data Summary/Discussion: Across the total 150 cm subsampled rows, AL germination at Palouse sites ranged from 5 to 50 seedlings, and OG germination ranged from 124 to 307 seedlings, with higher germination rates at Grey Duck Farm compared to Soil Stewards Farm. Upon harvest, weed biomass, alfalfa biomass, and orchardgrass biomass was higher at Grey Duck Farm compared to Soil Stewards farm; alfalfa biomass ranged from 21.3to 89.8 g, orchardgrass biomass ranged from 5.6 to 67.4 g, and weed biomass ranged from 202.4 to 651.8 g. Across the two farms, infiltration rates ranged from 0.86 to 600 cm/hr, and bulk density ranged from 0.71 to 1.51 g/cm3. Data from 2022 are still being analyzed in order to find significant differences in soil health indicators based on differing tillage and organic amendment treatments. Approximately 3,000 nematodes and arthropods have been processed and are currently being identified. Outcomes: Impacts of tillage with different levels of organic amendments on AL/OG establishment and first year growth have been demonstrated in two different climate/growing zones. Objective 2. Major activities: Earthworms, nematodes and arthropods were sampled at each of the plots described in objective 1. Data Collected: Earthworms biomass and density were measured.Earthworms were identified to the species level in the lab. In each plot, 9 nematode samples and 9 arthropod samples were collected. Data Summary/Discussion: Earthworm density ranged from 16to 480 individuals/m2.Earthworm biomass ranged from 0to 398 g/m2. Three species (all exotic) of earthworms were identified: Aporrectodea tuberculate, Aporrectodea trapezoides, and Lumbricus terrestris. Nematodes and arthropods collected in 2022 are still being identified. Approximately 9,000 nematodes are arthropods have been processed from these samples and are currently being identified.

Outcomes: This data set represents the first state-wide assessment of soil macro and mesfauna in organic systems in Idaho. When completed the data set will allow us to better understand the relationship between these organisms and soil health and management. Objective 3. Major activities: Soil was sampled along the 3 transects at each of the 10 sites (5 in the Palouse and 5 in the Magic Valley) established in 2021..Data Collected: Chemical, biological, and physical indicators of soil health were analyzed. Arthropods and nematodes were sampled. Data Summary/Discussion: Across the five sites in the Palouse, physical soil measurements showed that bulk density ranged from 0.63to 1.48 g/cm3and the water infiltration rate ranged from 1.65 to 85.7 cm/hr. Soil pH ranged from 5 to7.5, the soil organic matter ranged from 1.8 to9.6%. The Haney soil health score ranged from 4.5 to 32.9 across the five farms. Additionally, available N ranged from 4.9 to 50.9 mg/kg, the available P from 6.2 to 594.4 mg/kg, and the available K from 14.0 to 545.0 mg/kg. In terms of biological indicators, the microbial active carbon (POXC) ranged from 186.8 mg/kg to 1164 mg/kg andearthworm density ranged from 0to 800 individuals/m2.Analysis of 2022 samples is underway and will allow more in-depth analysis of soil health at these sites. Outcomes: With completion of 2022 analyses, two complete years of data will be available to determine trends in soil health across sites and time. This is the first state-wide assessment of soil health in organic systems in Idaho. Objective 4.Major activities: Samples collected in 2021 have been analyzed for a wide range of soil health indicators. 2022 samples have been collected and analyses will be completed by spring 2023. The first review of soil health data with framers and other stakeholders has been scheduled for Dec. 1, 2022 and will focus on the Haney soil health data, which has been completed for both sites.Data Collected: Chemical, physical and biological indicators of soil health including the Haney suite. Data Summary/Discussion: Statistical analysis of the completed soil health indicators for 2021 and 2022 are underway and will be reviewed by project PIs and stakeholders in our Dec. 1, 2022 meeting.Outcomes: One suite of soil health indicators (Haney) has been analyzed for the first two years of the project. Statistical analyses are currently being completed. Stakeholders will be included in the analysis to start the work of developing soil health targets. Objective 5.Major activities: Using our stakeholder list established in year 1, organic researchers, food system professionals and members of the public as well as all certified organic growers in Idaho were invited to the first ever state-wide Organic Workshop in Idaho. The online workshop was held on Feb. 17, 2021.Data Collected: Pre and post-surveys were developed to characterize the population of farmers, professionals and community members who are interested and/or practicing organic production. Surveys also provided feedback on the perceived quality and value of the workshop among participants.Data Summary/Discussion: Seventy-two individuals registered for the workshop, and 49 attended. The majority of farmers (61%) who took the pre-survey reported using only organic management practices. The most important areas of interest among farmers completing the pre-survey were reducing tillage and incorporating cover crops. Participants rated the workshop highly and most appreciated the ability to connect with other organic growers in the state. Outcomes: Stakeholders, including farmers, are now aware of the project goals and have recieved an introduction to soil health. Farmers indicated that they appreciated the opportunity to network and this meeting created a strong foundation for creating educational and support networks. Objective 6. Major activities: An Organic Farming Workshop was hosted, abstracts submitted and the project was discussed at a field day in northern Idaho.Data Collected: Farmers participating were surveyed to determine the precieved value of participating in the workshop. Attendence and participation was recorded.Data Summary/Discussion: Project dissemination has been initiated and will be a larger part of the project in year 3, when two full years of data are completed and ready to share.Outcomes: Workshops will better inform farmers of how to manage for soil health and apply research results. Data shared at scientific meetings will help inform other research and create a greater network to focus on organic farming and soil health. **Publications** - Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: Temmen, D. 2022. Variation in soil health indicators across certified organic farms in the Inland Pacific Northwest. ASA, CSSA, SSSA International Annual Meeting. Baltimore, MD. Available online at: https://scisoc.confex.com/scisoc/2022am/meetingapp.cgi/paper/142902 - Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: Romano, A.W., L.R. Schott. Soil health in organic systems of the western high desert. ASA, CSSA, SSSA International Annual Meeting, Baltimore, MD. Available online at: https://scisoc.confex.com/scisoc/2022am/meetingapp.cgi/Paper/144805 **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience:The target audience for this project includes the following groups. 1. agronomists, soil scientists and entomologists at other research institutes and within USDA 2. Extension educators from Idaho and other states where organic farming is of interest 3.Organic farmers and farmers interested in transitioning to organic 4. Stakeholders who interact with organic farms from a food systems perspective. Changes/Problems: Replicated plots in northern Idaho will be one year behind plots in southern Idaho due to crop failure and extreme competition from weeds. This was caused by extreme heat and drought experienced in spring/summer 2021, and the fact that these organic-certified sites had not been cultivated previous to our study. Plots will be reseeded in spring 2022. Alfafa yield and quality were not tested in southern Idaho. A more detailed sampling plan has been developed to ensure that the data will be collected in year 2. One of the farmer-collaborators in southern Idaho dropped out of the study prior to the beginning of the growing season. The site was, therefore, moved to land at the University of Idaho Kimberly Research and Extension

Center. The method for microbial biomass has been changed from fumigation/incubation to Phospholipid Fatty Acid (PFLA)because it will provide more detail on the function of the microbial community at each site/plot. Finally, COVID-19 restrictions limited our ability to gather stakeholders and disseminate information at meetings and conferences. What opportunities for training and professional development has the project provided?Two Masters-level graduate students were recruited and started work on this project in Summer 2021. The students are receiving training in field collection and laboratory methods as well as data management. A research support scientist was able to travel to another university to recieve further training on nematode identification. How have the results been disseminated to communities of interest? Project dissemination was somewhat limited due to COVID. The project was discussed at an organic field day in northern Idaho and through communications with relevant Extension Educators across the state of Idaho. What do you plan to do during the next reporting period to accomplish the goals?Replicated plots utilized for testing disturbance and organic matter input treatments will be reseeded to an alfafa/orchard grass mixture in spring 2022. The replicated plots in both southern and northern Idaho will continue to be sampled to determine any impacts of the treatments. The time-series transects at all 10 sites will be sampled in the spring for chemical, physical and biological soil health indicators. Stakeholders will be gathered for the initial project meeting and initial project data will be disseminated at meetings and conferences. Survey instruments will be finalized and team and producer evaluation data will be collected. **Impacts** What was accomplished under these goals? Objective 1 Major Activities: Replicated plots were created in two locations in both southern (Magic Valley) and northern Idaho (Palouse region) to determine differential impacts of tillage disturbance and organic inputs (compost). All tillage/soil management practices were recorded to determine disturbance level. Three levels of disturbance were created and either organic (compost) or processed organic fertilizers were added. Plots were seeded to alfalfa and orchardgrass mixtures. Due to record heat and drought conditions, stand failure was experienced at both sites in northern Idaho. Sites will be reseeded in spring 2022. Data Collected: Initial soil health sampling (chemical, physical and biological indicators) was conducted. Data Summary/Discussion: Most soil analyses (microbial biomass, pH, total carbon and nitrogen, etc.) are currently being conducted in our laboratories and data are not yet available. Infiltration rates at the Colfax site in the Palouse region averaged 11.5 (+/- 3.1) cm/hr compared to 7.7 cm/hr (+/- 1.7) at the Soil Stewards site. Bulk density ranged from 1.01 to 1.05 g/cm3 at the Colfax site and between 1.21 and 1.45 g/cm3 at the Soil Stewards farm. Despite greater density (indicating compaction), average earthworm density was greater at the Soil Steward site (48 +/- 18) than at the Colfax site (11 +/- 5 individuals/m2) at the dryer Colfax site. Outcomes: At this early stage in the project, outcomes are limited. We have gathered baseline data that will be utilized to determine treatment differences. Objective 2 Major Activities: Nematodes, arthropods and earthworms were collected from the replicated plots described in objective 1. Nematodes and arthropods were extracted from soil samples in the laboratory. Data Collected: Nematodes, arthropods and earthworms collected were counted and subsamples will be identified to species. Data Summary/Discussion: The density of nematodes and arthropods, once sorted and identified, will be utilized as baseline data along with earthworm density data (reported above). Samples collected in the remaining two years of the project will be compared to determine any treatment effects. Outcomes: Once sample analysis is complete, we will have quantified baseline conditions that will be utilized to determine how three different combinations of disturbance and organic amendments influence soil biotic communities. Objective 3 Major Activities: Transects were established at five sites in each region of study. At each site, three transects were developed and samples collected. Soil health analyses are still in progress. A survey was developed to determine site histories and management. The survey data will be utilized to help understand the structure of soil health data in relation to climate and management. Data Collected: Chemical, biological and physical indicators of soil health are currently being analyzed. Management data will be included in the farmer surveys. Data Summary/Discussion: While field work was completed in the summer and fall of 2021, laboratory analyses are still currently being conducted. Earthworm density ranged between 0 and 437 individuals/m2 across Palouse sites and does not appear to correlate to the number of years under organic management. At these same sites, infiltration rates ranged from 17.5 to 41.9 cm/hr. Outcomes: Farmer collaborators were identified and sites and transects established. Soil health indicators are currently being analyzed. Objective 4 Major Activities: Stakeholders have been identified through a variety of means. Extension educators engaged in sustainable agriculture, small farms and organic production were contacted and asked to participate in the project. Lists of organic farms with contact information from the organic registry website were made. Workshops and other meetings with these stakeholders were not held in 2021 because 1) soil health data was still being generated and 2) COVID restrictions were still in place for a portion of the year. Data Summary/Discussion: Data from this objective will include the feedback from stakeholders regarding the usefulness of each soil health indicator in each region. Outcomes: At this early stage in the project, the major outcome has been the development of a stakeholder list. These stakeholders will be gathered to being work on this objective in winter 2022, assuming that travel and gatherings will continue to be allowed. If not, we will redesign our workshops to be shorter and communicate through an online, distance communication software such as Zoom. Objective 5 Major Activities: Stakeholders have been identified through contacts with extension educators and others in each region of study as described in Objective 4. Workshops were not held in 2021 due to COVID restrictions and the need to establish relationships that are best fostered through in-person interactions. Groups will start meeting in 2022. Data Collected/Summary: This objective does not include data collection in the traditional sense. A survey has been developed and will be fine-tuned to assess the effectiveness of grower workshops. Outcomes: Much of the work related to this objective will take place in 2022. At this early stage the outcomes are limited to greater knowledge of the project among extension educators. Objective 6 Major Activities: Project dissemination has been limited due to the early stage of this project and limitations on meetings put into place in 2021. Awareness of the project has been increased through interactions with extension educators throughout Idaho. The project was also highlighted at a field day held in northern Idaho in fall 2021. Data Collected/Discussion: Presentations and publications will be documented. Extension-based trainings will be assessed to determine their impact and effectiveness. Outcomes: Outcomes are limited due to the early stage of this project. **Publications**

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The Development of a Whole Farm Organic Transition Tool to Help Advise Producers

Accession No.	1023613
Project No.	KS10201757
Agency	NIFA KAN\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51106-32377
Proposal No.	2020-02389
Start Date	01 SEP 2020
Term Date	31 AUG 2023
Grant Amount	$412,960
Grant Year	2020
Investigator(s)	Ibendahl, G. A.

NON-TECHNICAL SUMMARY

The transition to organic crop production may be difficult for producers to evaluate. Producers who would be receptive to organic crops have neither the necessary tools nor the relevant information needed to evaluate the potential profitability of these crops. Complicating the analysis is the transition window where organic practices must be followed but the crop produced must be sold as non-organic. This presents problems for producers as they must decide how fast to transition and how best to make changes to their inputs and machinery requirements. There is no comprehensive, easy to use, whole farm transition tool that can help Extension personnel make recommendations about which organic crops to grow, how quickly to transition to organic production, and what is the expected profitability before, during and after the transition. Our objective in this proposal is to determine the production practices of organic producers, estimate transition costs, estimate the inputs needed during the transition, develop a whole farm transition profitability tool, and produce estimates of the profitability both during and after the organic transition.This project is unique because it provides one of the few tools for Extension personnel and farmers to estimate the profitability of transitioning to organic crop production and how quickly the transition should take place. The project also provides a way for producers to compare their expected whole farm profitability during the organic transition to the farm profitability from remaining with conventional crops. With this project, we are addressing Priority 4; overcome barriers to organic transition.

OBJECTIVES

The long-term goal is to provide the most effective decision aids and the most complete and accurate information about the profitability of transitioning to organic crops so that any potential producer of organic crops can make good decisions about whether or not to actually grow organic crops and how quickly they should make the transition.Ourobjectivein this proposal is to determine the production practices of organic producers, estimate transition costs, estimate the inputs needed during the transition, develop a whole farm transition profitability tool, and produce estimates of the profitability both during and after the organic transition. The specific objectives of the project are:1) Identify the production practices needed to transition to organic crop production.\Extension objective\Our approach will be to identify organic producers and survey them to find out how they made the transition to organic production.2) Estimate the extra equipment needed for an organic transition.\Research objective\Our approach will be to take the practices identified from objective (1) and calculate the machinery requirements needed to accomplish those production practices. We will then use standard agricultural engineering formulas to estimate the costs of that equipment. These formulas take the initial cost, the expected life and salvage value, and apply coefficients developed by the engineers to calculate a cost per acre for a piece of machinery.3)Develop a whole farm organic transition tool that is clear, easy to use, and that produces accurate, timely, and relevant information about the profitability of organic production both during and after the transition and then compares that to a baseline of only growing conventional crops.\Extension objective\Our approach will be to take the Kansas State Organic Budget Generator (which is currently being developed by one of the PDs) and modify it to examine multi-year crop rotations which would include a transition to organic crops. The tool would thus examine whole farm profitability over time instead of just a single crop acre for a given year.4)Estimate the expected cost of transitioning to organic production at various conversion rates.\Research and education objective\Our approachwill be to take the production practices identified in objective (1), the extra equipment identified in objective (2), and then by using the whole farm organic transition tool developed in objective (3), calculate the most profitable transition scheme for producers considering organic production.5)Distribute the whole farm organic transition tool developed in objective (3) and the organic crop transition plans developed in objective (4) to Extension personnel across the country. \Education objective\Our approach will be to take whole farm organic transition tool and the associated profitability analyses that were produced and first make them available on the Kansas State University AgManager.info website. Next the tool and the analyses will be provided to state Extension specialists across the country who work with budgets or organic crops.

APPROACH

Objective 1 - Identify the production practices needed to transition to organic crop production.Production practices will be identified in various regions across the country. We plan to use the nine USDA-ERS farm resource regions: Eastern Uplands, Heartland, Southern Seaboard, Northern Crescent, Fruitful Rim, Northern Great Plains, Basin and Range, Prairie Gateway, and Mississippi Portal. Within these nine regions, we will identify the major organic crop and then identify the production practices used to grow this crop organically and conventionally.A set of surveys to key state Extension specialists within each region will help us identify the needed production practices. The PD has extensive experience developing crop budgets in both the south and the north central regions. In addition, through regional and national budgeting workshops and other Extension activities, the PD knows most of the Extension specialists at other states working to develop crop budgets. These other Extension specialists can provide us with the production practices we need or else they can put us in touch with the individuals who would know the production practices of a given organic crop.Objective 2 - Estimate the extra equipment needed for an organic transition.The production practices identified in objective (1) will guide the selection of extra equipment needed for both the transition phase and also after the conversion to organic production is complete. Part of the difficulty of converting to organic production is that some machinery may be unique to either organic or conventional production. Thus, the transition phase may require more types of equipment that is used less frequently than either before or after the transition. These fixed assets that cannot be priced on a per unit basis. For example, the use of a tractor and a cultivator for mechanical weed control requires two assets, a tractor and a cultivator, that have a multi-year life. That is, the input is not used up when applied.Our approach for machinery costs will be to use the technique based on equipment ownership and the use of agricultural engineering formulas but also allow for the use of custom machinery operations. A dual approach like these provides maximum flexibility to record machinery expenses. Even if a producer plans on owning the equipment in the long run, a short-term solution, when an organic transition is starting and the number of organic crop acres are less, is to use a custom operation. As the number of organic acres increases, a producer is then likely to start buying the needed additional equipment.Objective 3 - Develop a whole farm organic transition tool that is clear, easy to use, and that produces accurate, timely, and relevant information about the profitability of organic production both during and after the transition and then compares that to a baseline of only growing conventional crops. Development of the whole farm organic transition tool. The new tool being proposed for this project will build on the K-State organic budgeting tool currently being finished. Instead of just producing a single budget the whole farm organic transition tool will build a profitability analysis for an entire crop rotation, for the entire farm, and over a number of years. Since the tool is designed to estimate profitability both during and after the organic conversion, the number of years allowed by the tool will be an input to the model. Also added as inputs will be the specific crops to be grown and the number of acres per year of each crop. The transition years will be included as organic budgets but with a different set of output prices since the transition years crops cannot be sold as organic. The feasibility of converting to organic will be measured by also developing a whole farm profitability analysis of the farm remaining in conventional crops. This part of the analysis will serve as the baseline. Since the whole farm organic transition tool will be populated with a set conventional crop budgets, organic crop budgets, and transition years budgets, the tool should work well for this comparison.The development of a whole farm profitability tool will be rather unique even among those producers just growing conventional crops. The PDs have had discussions with the Kansas Wheat Board to look at wheat production in rotation with other crops. Just in isolation, wheat is currently one of the least profitable crops in the state. However, there are some advantages that including wheat in a rotation provides such as less weed control needed between crops, possible water conservation, etc., The whole farm organic transition tool discussed here is able to model these advantages. Objective 4 - Estimate the expected cost of transitioning to organic production at various conversion rates. One of the limitations of the whole farm organic transition tool as planned is that it provides no easy way to calculate how quickly land should be converted into organic production. It is possible to do this, but it would require a trial and error approach. A better way to provide this transition speed estimate is to formulate a whole-farm linear programming model. The use of linear programming (LP) to evaluate the profitability and viability of different farming operations has been used numerous times. Recent publications have evaluated integration of mechanical weed control with banded herbicide application to control herbicide resistant weeds, timeliness of field operations from adding additional acreage to an existing farm, how federal policy impacts farm level production in the Lower Mississippi River Basin. For the current research, the LP model will be formulated to determine how profit maximizing producers allocate acreage across conventional and organic production systems given machinery in inventory and a range of price ratios. LP programming, or linear optimization, is a method to achieve the best outcome (such as maximum profit or lowest cost) in a mathematical model whose requirements are represented by linear relationships. The transition time question facing producers can be modeled with LP programming because all the constraints facing producers can be written as either linear equalities or linear inequalities. LP programming has been used for many applications in agriculture and is a common modelling technique by economists. LP programming will give an exact answer for how quickly farmers should transition their farm to organic production. The solution provided by the LP model than then be plugged into the whole farm organic planning tool for producers to use as a baseline.Objective 5 - Distribute the whole farm organic transition tool developed in objective (3) and the organic crop transition plans developed in objective (4) to Extension personnel across the country.The whole farm organic transition tool and the transition to organic analysis will be made available on the Kansas State University AgManager.info website and also made available to state Extension specialists across the country working in crop budgets. The AgManager.info website is one of the premier sources for farm management information and generates a lot of traffic. The tool and the budgets should get lots of exposure just from this site. There are several farm management committees across the country and the tool and the budgets will be provided through this resource as well. Progress 09/01/23 to 08/31/24 Outputs Target Audience:The primary target audience for this project includes farmers, agricultural lenders, and other stakeholders involved in production agriculture who are considering a transition to organic crop production. During the reporting period, project efforts were primarily focused on the development of the Organic Transition Decision Aid. As a result, outreach activities were largely centered on engaging farmers to gather input and feedback to inform the tool\'s design and functionality. This farmer-focused engagement has been critical to ensuring the decision aid will be practical, user-friendly, and aligned with the real-world needs and concerns of producers evaluating a shift to organic practices. Changes/Problems:The PI\'s daughter continues to battle seizure issues which has resulted in project delays as many test (some out of state) have been needed. Fortunately, all the testing lead to a brain surgery in November of 2024 to implant an RNS device that is supposed to help with seizure control. The outlook is promising but it could take a year for the device to become effective. What opportunities for training and professional development has the project provided?Crop budgets are a critical component in estimating net income and determining the cost of production. Much of the principal investigator\'s (PI\'s) Extension programming is grounded in the use of budget outputs generated through the ongoing development of the Organic Transition Budget Tool. Building on this work, the PI has adapted elements of the tool to support additional Extension activities across Kansas. Specifically, the tool is being used to assist county Extension agents in evaluating various crop combinations and analyzing the financial implications of different lease arrangements. These applications enhance the decision-making capacity of both agents and the producers they serve. Training and dissemination efforts are ongoing and include presentations at county-level meetings, dedicated training sessions for Extension agents, and the publication of related materials on AgManager.info. This expanded use of the budgeting tool ensures that the investment in organic transition modeling also contributes broadly to production agriculture decision support throughout the state. How have the results been disseminated to communities of interest?Currently, AgManager.info is the main source of distribution. However, the PI is also providing information via training videos on YouTube and additional posts on Substack. What do you plan to do during the next reporting period to accomplish the goals?The budget development tool and organic transaction is an on-going process. Changes are continually be made throughout the year. With bug fixing and interface improvements continually occurring. Impacts What was accomplished under these goals? The development of the Organic Transition Budget Tool continues to serve as a core component of the principal investigator\'s (PI\'s) Extension programming. Budgeting remains the foundation of profitability analysis, and this tool is designed to support producers evaluating the financial implications of transitioning to organic crop production. The current configuration of the tool supports single-crop budgets, which can be layered to reflect more complex production systems. For example, irrigated crop budgets are developed by combining a standard crop budget with a separate irrigation component. This modular structure is being adapted to support the unique financial modeling needs of organic transition scenarios. Organic and conventional crop production share many common inputs\--particularly in terms of machinery and equipment\--though they differ in pesticide and fertilizer use. Fortunately, the software architecture accommodates these differences with minimal changes, allowing for the integration of organic inputs into the existing database. The PI is actively working to enhance the tool\'s capacity to handle multi-year transition budgets, enabling users to model a progression from conventional to organic systems over time. This functionality will allow for a more accurate estimation of transition-related costs and the long-term financial impacts. Recent improvements to the decision aid include enhanced user navigation, updated documentation, and expanded input databases. The machinery cost module now allows users to choose between using actual owned equipment or referencing custom rate schedules. Currently, the tool includes both the Kansas and Iowa state custom rate surveys. This added flexibility is particularly valuable for organic producers, who often rely more heavily on mechanical weed and pest control methods than their conventional counterparts. These ongoing enhancements are critical to ensuring that the tool remains a practical and reliable resource for producers, lenders, and advisors considering or supporting a transition to organic crop production. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Ibendahl, G., 2024. Estimating Corn Production in the U.S. Based on Early July Crop Estimates. Selected Poster. International Farm Management Association Congress, Saskatoon, SK Canada, 7/7 to 7/12/24. Progress 09/01/22 to 08/31/23 Outputs Target Audience: The target audience is farmers, lenders, and others with an interest in production agriculture who are interested in making a transition to organic crop production. During this period we were mainly in product development of the organic transition decision aid so we mainly reached out to farmers to get input. Changes/Problems:The death of the PI\'s mother in April of 2023 slowed down work on the project. These issues are still ongoing as settling the estate has run into difficulties. In addtion, the PIs daughter has seen the severity and frequency of her seizures increase over the past year. This has resulted in more testing at KU med. What opportunities for training and professional development has the project provided? Budgets are a big part of estimating net income and cost of produciton. Most of the PI Extension work is based on the output from crop budgets and the budgeting too. The main PI is using offshoots of the work on the organic budgeting tool to help Kansas county Extension agents analyze different crop combinations and also to analyze different lease types. This training is occurring as publication to AgManager.info and also at county meetings and dedicated Extension agent trainings. How have the results been disseminated to communities of interest? Currently, AgManager.info is the main source of distribution. What do you plan to do during the next reporting period to accomplish the goals? The budget development tool and organic transaction is an on-going process. Changes are continually be made throughout the year. Impacts What was accomplished under these goals? The work of the organic budget transition tool continues to server as the basis of the main PI\'s Extension program. Bugets are the backbone of any type of profitability analysis. The tool as currently configured can handle a single crop and budgets can actually be stacked together. In the current version, a irrigated budgets are produced by combining a crop budget with a separate budget for just the irrigation components. This type of framing will also come into play for the transition to organic production. Organic and non-organic production share many of the same inputs (other than pesticides and fertilizers). That is both organic and non-organic production require the use of machinery and equipment that has much overlap. While organic produciton uses a different set of fertilizers and pesticides, those same inputs still fit into the software model without major changes to the database. Currently the PI is in the process of converting the budget generator to handle transition issues. The major changes will be an ability to develop multi-year budgets that transition from conventional to organic production. The tool as modified can combine budgets into a system and this will be used to estimate transition costs. In addition, the PI is adding more organic fertilizers and pesticides into the tool. Changes to the decision aid include cleaning up of the tool, making it easier for users to navigate, adding documentation, and enhacing the databases of inputs. The machinery side can now use a producer\'s owned machinery as well as base machinery costs on the a custom rate schedule. There are currenty two sets of custom rates in the model, the Kansas state custom rate survey and the Iowa state custom survey. The combination of using owned machinery and as well as custom rates gives organic produces a lot of flexibility for incorporting machinery costs into their model. This is important as organic producers are much more dependent on using mechanical methods of weed and pest control than are conventional producers. Publications Type: Websites Status: Published Year Published: 2023 Citation: G. Ibendahl, D. O\'Brien, L. Haag, S. Lancaster, and J. Holman. 2023. Irrigated Corn (center-pivot) Cost-Return Budget for Crop Year 2024. November 1, 2023. Type: Websites Status: Published Year Published: 2023 Citation: G. Ibendahl, D. O\'Brien, J. Holman, S. Lancaster, and L. Haag. 2023. Wheat (W-S_C-F Rotation) Cost-Return Budget in Southwest KS for Crop Year 2024. November 1, 2023. Type: Websites Status: Published Year Published: 2023 Citation: G. Ibendahl, D. O\'Brien, S. Lancaster, and L. Haag. 2023. Wheat (W-S_C-F Rotation) Cost-Return Budget in Northwest KS for Crop Year 2024. November 1, 2023. Type: Websites Status: Published Year Published: 2023 Citation: G. Ibendahl, D. O\'Brien, J. Holman, S. Lancaster, and L. Haag. 2023. Wheat (W-F) Cost-Return Budget in Southwest KS for Crop Year 2024. November 1, 2023. Type: Websites Status: Published Year Published: 2023 Citation: G. Ibendahl, D. O\'Brien, S. Lancaster, and L. Haag. 2023. Wheat (W-F) Cost-Return Budget in

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Revised Net Farm Income Projections for 2023 and 2024 - September Update. AgManager Publication - GI-2023.11, September 10, 2023. Type: Websites Status: Published Year Published: 2023 Citation: Ibendahl, G. 2023. Updated 2023 Crop Budgets and Comparison with Previous Estimates. AgManager Publication - GI-2023.08, May 16, 2023. Type: Websites Status: Published Year Published: 2023 Citation: Ibendahl, G. and D. OBrien. 2023. A Preliminary Estimate of 2022 Kansas Net Farm Income and a Projection for 2023. AgManager Publication - GI-2023.02, February 21, 2023. Type: Conference Papers and Presentations Status: Published

Year Published: 2023 Citation: Ibendahl, G. 2023. \"Net Farm Income Projections for 2022 and 2023. 2 presentations at Risk and Profit Conference, Department of Agricultural Economics, Kansas State University, Manhattan, KS. August 17 and 18, 2023. Type: Websites Status: Published Year Published: 2023 Citation: G. Ibendahl, D. O\'Brien, S. Lancaster, and D. Shoup. 2023. Wheat Cost-Return Budget in Southeast Kansas for Crop Year 2024. November 1, 2023. Progress 09/01/21 to 08/31/22 Outputs Target Audience:The target audience is farmers, lenders, and others with an interest in production agriculture who are interested in making a transition to organic crop production. During this period we were mainly in product development of the organic transition decision aid so we mainly reached out to farmers to get input. Changes/Problems:The main PI had some serious health issues this past wint and into spring. He ended up having his gall bladder removed. In addition, the main PI\'s mother had a major stroke in January and ended up passing in April. These two issues resulted in the PI not being available for long stretches. What opportunities for training and professional development has the project provided?Budgets are a big part of estimating net income and cost of produciton. Most of the PI Extension work is based on the output from crop budgets and the budgeting tool How have the results been disseminated to communities of interest?Currently, AgManager.info is the main source of distribution. What do you plan to do during the next reporting period to accomplish the goals?The budget development tool and organic transaction is an on-going process. Changes are continually be made throughout the year, Impacts What was accomplished under these goals? Organic and non-organic production share many of the same inputs (other than pesticides and fertilizers). That is both organic and non-organic production require the use of machinery and equipment that has much overlap. While organic produciton uses a different set of fertilizers and pesticides, those same inputs still fit into the software model without major changes to the database. Currently the PI is in the process of converting the budget generator to handle transition issues. The major changes will be an ability to develop multi-year budgets that transition from conventional to organic production. The tool as modified can combine budgets into a system and this will be used to estimate transition costs. In addition, the PI is adding more organic fertilizers and pesticides into the tool. Changes to the decision aid include cleaning up of the tool, making it easier for users to navigate, adding documentation, and enhacing the databases of inputs. The machinery side can now use a producer\'s owned machinery as well as base machinery costs on the a custom rate schedule. There are currenty two sets of custom rates in the model, the Kansas state custom rate survey and the Iowa state custom survey. The combination of using owned machinery and as well as custom rates gives organic produces a lot of flexibility for incorporting machinery costs into their model. This is important as organic producers are much more dependent on using mechanical methods of weed and pest control than are conventional producers. Publications Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, D Shoup, 2022. Wheat Cost-Return Budget in Southeast Kansas \| Average Yield \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, L Haag, S Lancaster, J Holman, 2022. Irrigated Corn (center-pivot) Cost-Return Budget \| Northwest Kansas (ave yields) \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, J Holman, S Lancaster, L Haag, 2022. Wheat (W-S_C-F) Rotation) Cost-Return Budget in Southwest KS \| Average yield \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, L Haag, 2022. Corn Cost-Return Budget (W-C-F Rotation) in Northwest Kansas \| Average yields \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, S Duncan, 2022. Corn Cost-Return Budget in North Central Kansas \| Average yields \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, D Shoup, 2022. Corn Cost-Return Budget in South Central Kansas \| Average yields \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, S Duncan, 2022. Corn Silage Cost-Return Budget in Northeast Kansas \| Average yields \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, D Shoup, 2022. Grain Sorghum Cost-Return Budget in South Central Kansas \| Average yields \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, S Duncan, 2022. Soybean Cost-Return Budget in North Central Kansas \| Average yields \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, L Haag, 2022. Alfalfa Cost-Return Budget in Northwest Kansas \| Average yields \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, M Stamm, J Holman, 2022. Canola Cost-Return Budget in South Central Kansas \| Average yields \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, S Duncan, 2022. Oil-Type Sunflowers Cost-Return Budget (Dryland Double-Crop) \| Central and Eastern KS - Average yields \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, D Shoup, 2022. Double-Crop Soybeans Cost-Return Budget \| Southeast KS and adjacent areas (Average yields) \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, J Holman, D Shoup, 2022. Forage Sorghum Silage Cost-Return Budget in South Central KS \| Average yields \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, S Duncan, L Haag, 2022. Cotton Cost-Return Budget (Dryland) \| Southeast KS - Average yields \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, S Duncan, 2022. Irrigated Soybeans (center-pivot) Cost-Return \| North Central Kansas - Average yields \| Nov-01-2022 Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G., D O\'Brien, S Lancaster, 2022. Irrigated Double crop - Oil-Type Sunflowers - Cost-Return Budget \| Western KS - Limited water - Average yields \| Nov-01-2022 Type: Other Status: Published Year Published: 2022 Citation: Ibendahl, G. 2022. \"USDA Prices Paid Index Update - October 2022. AgManager Publication - GI-2022.35, October 13, 2022. Type: Other Status: Published Year Published: 2022 Citation: bendahl, G. 2022. \"The Price Premium for Diesel Fuel. AgManager Publication - GI-2022.36, December 13, 2022. Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G. 2022. Oil Price Outlook - October 2022. AgManager Publication - GI-2022.34, October 10, 2022. Type: Other Status: Published Year Published: 2022 Citation: Ibendahl, G. and D. O\'Brien. 2022. Revised Net Farm Income Projections for 2022 and 2023 - September Update. AgManager Publication - GI-2022.31, September 6, 2022. Type: Websites Status: Published Year Published: 2022 Citation: Ibendahl, G. \"An Estimate of Soybean Production From the 18 Leading Soybean States.\" farmdoc daily (12):115, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, August 4, 2022. (6,087 page views) Type: Other Status: Published Year Published: 2022 Citation: Ibendahl, G. \"An Estimate of Corn Production From the 18 Leading Corn States.\" farmdoc daily (12):111, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, July 27, 2022. (6,516 page views) Type: Other Status: Published Year Published: 2022 Citation: Ibendahl, G. 2022. \"The Russia-Ukraine Conflict and the Effect on Fertilizer\" AgManager Publication - GI-2022.10, March 8, 2022. Type: Other Status: Published Year Published: 2022 Citation: Ibendahl, G. 2022. \"Fertilizer Prices, A Worst Case Scenario?\" AgManager Publication - GI-2022.09, February 17, 2022. Type: Other Status: Published Year Published: 2022 Citation: Ibendahl, G. 2022. \"An Update on Farm Expenses by Category Percentage.\" AgManager Publication - GI-2022.08, February 16, 2022. Type: Other Status: Published Year Published: 2022 Citation: Ibendahl, G. and D. O\'Brien. 2022. \"January 2022 Update for Crop Budgets.\" AgManager Publication - GI-2022.03, January 20, 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Ibendahl, G. and D. O\'Brien. 2022. \"2023 KSU Crop Budgets and Managing Input Costs.\" Presentation at 2022 Agricultural Economics Agent Update Training. K-State Salina campus, Salina, KS. 12/6/2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Ibendahl, G. 2022. \"Fertilizer and Energy Markets with Cost of Production Impacts.\" Presentation at 2022 Ag agent training session \"Preparing for Agricultural Challenges in 2023.\" Manhattan, KS. 10/17/2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Ibendahl, G. 2022. \"Net Farm Income Projections for 2022 and 2023. 2 presentations at Risk and Profit Conference, Department of Agricultural Economics, Kansas State University, Manhattan, KS. August 16, 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Ibendahl, G. 2022. Forecast for Input Prices, Inflation, and Net Farm Income. Presentation for Kansas Society of Farm Managers and Rural Appraisers. Winter Meeting. February 23-25, 2022. Type: Other Status: Published Year Published: 2022 Citation: Ibendahl, G. 2022. Implications for Energy Markets. Ukraine-Russia Conflict: Agricultural Ramifications Webinar, Department of Agricultural Economics, Kansas State University, Manhattan, KS. March 9, 2022. Type: Other Status: Published Year Published: 2022 Citation: Ibendahl, G. 2022. Effects on Fertilizer Inputs. Ukraine-Russia Conflict: Agricultural Ramifications Webinar, Department of Agricultural Economics, Kansas State University, Manhattan, KS. March 9, 2022. Type: Journal Articles Status: Under Review Year Published: 2022 Citation: Ibendahl G. 2022. A Decision Aid to Help Farmers Find the Minimum Cost Fertilizer Combination. Journal of Applied Farm Economics. (in second review as of 1/9/23). Type: Other Status: Published Year Published: 2022 Citation: Ibendahl, G. 2022. Update on Fertilizer and Energy. Ukraine-Russia Conflict: Agricultural Ramifications Webinar, Department of Agricultural Economics, Kansas State University, Manhattan, KS. June 22, 2022. **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience: We are currently expanding the budget generator tool to look at more than just an individual one-year crop budget. We have made some of the work from this project available to our county Extension agents and to farmers and lenders and others through AgManager.info Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?We have demonstrated this tool to Kansas Extension agents at a December 2020 agent training. How have the results been disseminated to communities of interest? The current version of the Excel budget and leasing tool is available on AgManager.info What do you plan to do during the next reporting period to accomplish the goals?We are continuing to add to our original budget generator tool so that multi-year frameworks can be examined more easily. In the meantime we are protyping ideas in Excel to see how they work before we program them into our budget generator tool with expanded capabilites **Impacts** What was accomplished under these goals? We have developed an Excel budget and leasing tool that allows users to combine budgets together to examine the profitability and risk effects of several budgets in combination. With this tool we can also examine various lease arrangements. This is the first step toward developing a decision aid that can analyze a multi-year framework of crop budgets and a transition to organic production. We are working to identify the production practices and the extra equipment needed for an organic transition Once we have all the pieces in place, we can address objective 4. This will likely occur later in the grant. **Publications** - Type: Other Status: Published Year Published: 2020 Citation: Ibendahl, G. 2020. \"Crop Budget and Leasing Tool.\" Application that uses the crop budgets to calculate leasing returns. 12/10/20. https://agmanager.info/land-leasing/land-rental-rates/lease-simulation-tool - Type: Other Status: Published Year Published: 2020 Citation: Ibendahl, G. 2020. \"General Overview of the crop budget and leasing tool.\" Instructional video. 12/10/20. https://www.youtube.com/watch?v=mELvOyIDPUw&feature=youtu.be - Type: Other Status: Published Year Published: 2020 Citation: Ibendahl, G. 2020. \"Comparing share vs cash leases. Instructional video. 12/10/20. https://www.youtube.com/watch?v=Ii4EoZPVfRc&feature=youtu.be - Type: Other Status: Published Year Published: 2020 Citation: Ibendahl, G. 2020. \"How to create a new budget from an existing budget.\" Instructional video. 12/10/20. https://www.youtube.com/watch?v=Gc51uFOdjuI&feature=youtu.be - Type: Other Status: Published Year Published: 2020 Citation: Ibendahl, G. 2020. \"How to simulate the expected returns from various lease arrangement.\" Instructional video. 12/10/20. https://www.youtube.com/watch?v=qCK-lnUKluY&feature=youtu.be - Type: Other Status: Published Year Published: 2020 Citation: Ibendahl, G. 2020. \"How to interpret the simulation results from the lease alternatives.\" Instructional video. 12/10/20. https://www.youtube.com/watch?v=dZzIt0vI870&feature=youtu.be

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Addressing Disbudding Pain and Alternative Options for Transitioning Organic Dairy Farms

Accession No.	1023662
Project No.	MIN-02-G08
Agency	NIFA MIN\
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Grant Amount	$499,794
Grant Year	2020
Investigator(s)	Heins, B.

NON-TECHNICAL SUMMARY

The long-term goal of this project is to increase and sustain organic dairy production and animal welfare through breaking barriers to organic dairy transition. One of the major barriers preventing transition to organic dairy production is dairy producers\' concerns about disbudding dairy calves and the challenges with animal health and welfare in an organic production system. The present proposal addresses these challenges through research involving the University of Minnesota\'s West Central and Research Center\'s certified organic dairy. We will develop methods to investigate the management feasibility to address pain and alternative options for disbudding for transitioning organic dairy farms. We will also evaluate markers of calf health, behavior and welfare to ultimately provide recommendations on best calf disbudding options for producers. Holstein and crossbred calves will be compared across and within each calf disbudding option. The results of this project will be valuable to organic dairy producers and will be disseminated to transitioning and organic producers and industry representatives throughout the United States. Our research results will be shared with our larger stakeholder groups through field days, conferences, publications, and webinars. Results from this study will provide research-based information on best options for pain management and disbudding in young calves which will help enhance the sustainability of US organic dairy farms and improve dairy industry\'s public perception.

OBJECTIVES

The long-term goal of this project is to increase and sustain organic dairy production and animal welfare through breaking barriers to organic dairy transition. One of the major barriers preventing transition to organic dairy production includes dairy producers\' concerns about dairy calf disbudding and the challenges with calf health in an organic production system.The long-term goal of this project is to enhance organic dairy animal welfare by advocating for science-based methods to alleviate the negative effects of disbudding. Producers and veterinarians of organic dairy cattle often express their critical need for evidence-based information concerning the efficacy of organic-approved treatments and management practices to reduce the adverse effects of disbudding on animal welfare. Critics of organic dairy practices are concerned that producers use ineffective approaches to care for animals.This project proposes to address an important portion of stakeholder critical needs by conducting controlled experiments to evaluate organic-approved treatments to mitigate acute pain caused by the disbudding procedure, and to evaluate long-term effects of disbudding on animal welfare in organic systems.Our goal is to identify and recommend management practices for disbudding young calves that will address a challenge but also likely provide a market opportunity for transitioning organic dairy producers, therefore improving dairy farm profitability. Specific objectives are: 1)To determine a dose of Salix extract that minimizes inflammation, 2) to evaluate the post-disbudding analgesic effects of Salix extract in calves, 3) evaluate effects of disbudding on weaning stress of calvesand evaluate effects of disbudding on transition stress in primiparous postpartum cows, and 4) disseminate project findings to stakeholders through hands-on and written communication and provide hands-on education for farmers. The success of this project will be evaluated by acceptance and implication of the project findings by organic and transitioning dairy farmers, and publications in farmer magazines, on extension websites, and in peer reviewed journals.

APPROACH

The organic dairy industry is in desperate need of methods to improve animal welfare, and horn removal represents a major identified issue threatening the industry\'s public image. Critics of the organic dairy industry constantly express concern about practices that jeopardize animal welfare, such as usage of alternative therapies that lack scientific proof of effectiveness. Furthermore, the use of unproven alternative therapies does not meet the legal requirements set by the NOP (i.e., suffering animals must be alleviated by an effective treatment method). A randomized crossover trial with repeated measures will be used to carry out the objective of activity 1. A 3-day washout period will be used to minimize carry-over effects, and treatment sequences will be orthogonal. This activity will be carried out over the course of 1 calving season using 10 female calves 4-8 weeks old\--the typical age range for disbudding. During each of the 5 treatment periods, the 10 calves will be randomly assigned to receive an anti-inflammatory treatment: 1)Flunixin meglumine (positive control; 2.2 mg/kg), 2) no treatment (negative control, 3) low dose of Salix extract (225 mg/kg of salicin), 4) medium dose of Salix extract (450 mg/kg of salicin) or 5) high dose of Salix extract (900 mg/kg of salicin). To evaluate the post-disbudding analgesic effects of Salix extract in calves, a generalized randomized complete block design with repeated measures will be used to carry out the objective. This study will be performed over the course of 1 calving season using 45 female calves in 5 pens (blocks) of 12 calves. Within a pen of 12 calves, nine calves will be randomly assigned to receive 1 of the following 3 treatments: 1) disbudded (positive control), 2) sham disbudded, or 3) Salix extract bolus + disbudded. The remaining 3 calves in each pen (n = 15) will not be disbudded and will be evaluated in further objectives. Sham disbudding will demonstrate handling stress, and including this group will improve the comparability and reproducibility of the experiment. Calves will receive their treatment in 15-minute intervals from 9000 to 1100 hours in a chute directly outside the pen. All calves will receive lidocaine (5 mL per horn bud of 2% lidocaine and oral boluses of either Salix extract or placebo. To evaluate long-term effects of disbudding on ability to cope with stressors, a generalized randomized complete block design with repeated measures will be used to investigate the long-term effects of disbudding on stress by following-up on calves during their weaning and transitioning periods. The selected sampling periods reflect life events in which animals are exposed to novel experiences and must cope with exaggerated stressors, which may be exacerbated by previous traumatic events. These periods were also chosen to evaluate the effects of disbudding before and after horns mature; once the horns mature, it will be impossible to delineate effects of disbudding and effects of horns. All analyses will be performed using SAS/STAT software using linear mixed models or using generalized linear mixed models. Normality of each outcome variable will be assessed on the raw-scale visually in a histogram prior to model selection and in diagnostics plots after each analysis to confirm assumptions are met. Transformations of variables will be applied depending on the type of data. For example, a natural log transformation may be appropriate for continuous data, whereas a square root transformation may be appropriate for count data. However, previous literature identified the deficits of transforming response variables without exploring other options. Therefore, Poisson regression models will be considered as viable options\--especially to analyze behavior count data\--to appropriately balance the bias and precision of the estimates. Furthermore, overdispersion is a common issue in count data, which often leads to an inflated Type I error. For the Poisson regression models, overdispersion will be evaluated by the Pearson chi-squared statistic, which should be approximately equal to the residual degrees of freedom. This can be statistically evaluated by calculating the probability of obtaining the observed Pearson chi-square statistic from a chi-square distribution with an expected mean equal to the residual degrees of freedom, where a small p-value suggests evidence of poor model fit. In this case, a negative binomial model will likely be a better option to account for the additional variance if the overdispersion is not due to specification errors of the Poisson model. Repeated measures models will include a normally distributed baseline covariate and covariance structures of either compound symmetry, first-order autoregressive, or spatial power to define the correlation between repeated observations. The Akaike information criterion (AIC) score will be used to compare models (e.g., compound symmetry vs. first-order autoregressive covariance structures, fixed vs. random block, etc.). Furthermore, diagnostic plots of residuals will be used as tools to assess final model fit. Finally, least squares will be used to estimate means and standard errors for linear mixed models. Back-transformed means will include back-transformed 95% confidence intervals for measures of error. Using frequentist hypothesis testing as the method of statistical inference, a statistical test (e.g., F statistic) with a p-value less than 0.05 (α \< 0.05) will declare a \"significant\" effect of the respective fixed effect, and a Tukey adjustment of the p-value will be made to compare multiple means. Progress 09/01/20 to 08/31/24 Outputs Target Audience:We have reached organic and conventional and transitioning dairy farmers across the United States. We have also provided information from the project to farmers and organic dairy industry representatives across the United States on the disbudding proejct. We have also trained 1 undergraduate and 1 graduate student in experimental design and collection of research data. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project has trained organic dairy producers on the alternatives for pain mitigation strategies in organic dairy calves. Many organic industry representatives and farmers were informed on dairy calf disbudding practices at the University of Minnesota during many conference presentations and podcast related to this project.We have also trained a graduate students in proper experiemental design, data collection, and analysis of data. A graduate stduent from Minnesota presented research on disbudding of dairy calves for organic produciton at the American Dairy Science Association meeting in June 2024 in West Palm Beach Florida. Also, this research was presented at The 57th Congress of the International Society for Applied Ethology (ISAE) in Curitiba, Brazil in July 2024. Results from the study were also presented in poster format at the February 2024 Marbleseed Organic Conference in LaCrosse, WI. How have the results been disseminated to communities of interest?Over 1000 people have attended presentations related to the objective research in the project. Results were disseminated to academic and audiences through peer-reviewed publications and abstracts presented at conferences. Presentations were also given that included farmers that have used our research results at grazing and organic conferences. We also have small focus group meeting with organic dairy farmers on a monthly basis where we showcased these results from the project. Furthermore, the information was disseminated on The Moos Room podcast. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Behavior and stress of first-lactation horned and dehorned organic dairy cattle during milking.Most US dairy producers disbud cattle. Raising cattle that are horned may more closely align with organic values of natural living while removing a welfare concern in early life. However, many producers perceive horns as a safety concern. Therefore, the objective of this study was to compare the behavior and salivary cortisol concentrations of dehorned (n = 37) and nondehorned (n = 14) first-lactation dairy cows at the University of Minnesota West Central Research and Outreach Center organic dairy in Morris, Minnesota. Cattle were milked twice daily during the first 8 d of first lactation. Handlers provided scores for ease of milking parlor entry and behavior in the milking parlor and recorded occurrences of kicks and stomping in the milking parlor. Saliva samples were collected immediately after milking. Linear mixed models were used for analysis of salivary cortisol and logistic regression was used for analysis of behavior with the fixed effects of dehorning status, days in milk, time of milking (a.m. or p.m.), and the interaction of dehorning status and days in milk with cow as a random effect. Dehorned cattle (163.3 pg/mL, 95% CI = 152.4 to 174.9) had higher salivary cortisol (P = 0.037) than horned cattle (142.3 pg/mL, 95% CI = 128.1 to 158.0). Mean salivary cortisol was lower (P \< 0.001) for increased days in milk from 203.2 pg/mL on d 1 to 140.4 pg/mL on d 8. Cortisol was higher (P = 0.006) during the morning (157.7 pg/mL, 95% CI = 147.6 to 168.3) than during the evening (147.4 pg/mL, 95% CI = 138.20 to 157.3). There was no effect of dehorning status, days in milk, or time for parlor entry or behavior scores or the occurrence of kicking or stomping in the milking parlor. The results indicate that dehorning may have long-term impacts on animal wellbeing. Dehorned dairy cattle had higher salivary cortisol than horned cattle and similar behavior during milking in the first 8 d of lactation. Publications Type: Conference Papers and Presentations Status: Accepted Year Published: 2024 Citation: Organic Milk Production in the USA. SDSU Dairy Science Class, March 1, 2024. South Dakota State University, Brookings, South Dakota Status: Accepted Year Published: 2024 Citation: Bacon, M., M.I. Endres, and B.J. Heins. 2024. Behavior and stress of first-lactation horned and dehorned organic dairy cattle during milking. J. Dairy Sci. Vol. 107, Suppl. 1 (Abstract #1582) p.155 Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: Organic Milk Production in the USA. SUSTAG 8000, November 9, 2023. University of Minnesota, St. Paul Type: Conference Papers and Presentations Status: Accepted Year Published: 2024 Citation: Improving the Health of Organic Dairy Cows & Heifers. Minnesota Organic Conference, January 12, 2024. St. Cloud, Minnesota Type: Conference Papers and Presentations Status: Accepted Year Published: 2024 Citation: Behavior and stress of primiparous horned and dehorned dairy cattle in the milking parlor. Marbleseed Conference. February 22-23, 2024, LaCrosse, Wisconsin Type: Conference Papers and Presentations Status: Accepted Year Published: 2024 Citation: Organic Milk Production in the USA. SDSU Dairy Science Class, March 1, 2024. South Dakota State University, Brookings, South Dakota Progress 09/01/22 to 08/31/23 Outputs Target Audience:We have reached organic dairy farmers across the United States. We have also provided information from the project to veterinarians, organic dairy industry representatives across the United States on the disbuddingproejct. A field day was offered for organic dairy producers, extension educators, and organic industry personnel during August 2023. We have also trained 5 undergraduateand 1 graduate student in experimental design and collection of research data. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project has trained organic dairy producers on the alternatives for pain mitigation strategies in organic dairy calves. Many extension educators and organic industry representatives were informed on dairy calf disbudding practices at the University of Minnesota organic dairy field day in August 2023. We have trained 2 undergraduate students on how to conduct research and outreach with disbudding and dairy calves. We have also trained a graduate students in proper experiemental design, data collection, and analysis of data.A graduate stduentfrom Minnesota presented research on disbudding of dairy calves for organic produciton at the American Dairy Science Association meeting in June 2023 in Ottawa, Canada. Results from the study were also presented in poster format at the February 2023 Marbleseed Organic Conference in LaCrosse, WI, and the 2023 UMN CFANS Graduate Research Symposium in St. Paul, MN. How have the results been disseminated to communities of interest?We had an in-person organic dairy day at the University of Minnesota West Central Research and Outreach Center in August 2023 to provide farmers and other industry personnel tools that they can take back to their farm when disbudding dairy calves. During the last year, over 150 people have attended the field days at the WCROC. Over 500 people have attended presentations related to the objective research in the project. Results were disseminated to academic and audiences through peer-reviewed publications and abstracts presented at conferences. Presentations were also given that included farmers that have used our research results at grazing and organic conferences. What do you plan to do during the next reporting period to accomplish the goals?The investigators on the project continue to review objectives and accomplishments of the project. We continue to collect data on the lactating cows that have been disbudded, as well as horned animals for cortisol and production parameters. During the last year of the project, we will draft peer review publications.Also, a graduate student will complete her PhD with the project and write 3 peer reviewed publications. Impacts What was accomplished under these goals? Effects of willow bark (Salix) on post-disbudding behaviors in dairy calves under organic management. The objective of this study was to evaluate the effect of an oral WB bolus on the behavior of 25 Holstein and crossbred heifer calves disbudded between 5 to 7 weeks of age. Calves were randomly assigned to one of three treatments: hot iron disbudding with lidocaine (5 mL per horn bud; n = 8), hot iron disbudding with oral WB (200 mg/kg; n = 10), or a \"sham\" disbudding (n = 7) in which an unheated iron is used to simulate the disbudding procedure as a control for handling stress. Tablets continuously recorded behaviors beginning 1 h before and ending 4 h after disbudding. Three observers, blinded to treatment, recorded the frequency of 6 behaviors (ear flicks, head rubs, head shakes, head scratches, tail flicks, transitions between lying and standing, and grooming) in 10-minute intervals using BORIS event-logging software. Logistic regression was used for analysis with the fixed effects of disbudding treatment, hour of observations, and the interaction of treatment and hour, with calf included in all models as a random effect. . The frequency of transitions was affected by treatment (P \< 0.05); the adjusted log mean number of transitions was 0.72 higher in calves receiving Salix compared to sham disbudding. Hour of observation had a main effect on head rubs (P \< 0.001) and grooming (P \< 0.001). Calves across treatments rubbed their heads more frequently in the first hour after disbudding than in hours 2 and 3 and groomed themselves more in the hour before disbudding than in hours 2 and 4 after. There was a main effect of the interaction of treatment and hour in head shakes (P \< 0.05. No effect of treatment, hour, or their interaction was observed in ear flicks, head scratches, tail flicks. These results indicate that Salix alone does not provide sufficient relief from disbudding pain. Effects of multimodal pain relief on stress in disbudded dairy calves under organic management. Disbudding is a standard procedure on most dairy farms, but organic options to alleviate pain are limited. White willow bark (WB) is commonly used to reduce pain in dairy calves under organic management. Dull It (DU) is a tincture of organic alcohol, apple cider vinegar, WB, St. John\'s Wort, chamomile, arnica, and fennel. The objective of this study was to assess the analgesic effects of oral WB and DU on the heart rates, salivary cortisol concentration, and lying behavior of disbudded Holstein and crossbred dairy calves. Calves were hot-iron disbudded between 5 to 7 weeks of age (Mean = 44 d) and randomly assigned to 1 of 3 treatments: Lidocaine only (LID; n=18), Lidocaine and DU (n=18), or Lidocaine and WB (n=17). Heart rates and lying behavior were recorded continuously during the study period. Saliva samples were collected from 30 randomly selected \"minimally-invasive\" (MIN) calves 1 hour before disbudding, at disbudding, 5 min, 10 min, and every 30 min until 240 min after disbudding; the remaining 23 calves served as a \"non-invasive\" (NI) group. There was no main effect of treatment on heart rate, cortisol concentrations, or lying behavior. The heart rates of MIN WB calves were above baseline in 30 (of 48) 5-min intervals post-disbudding (P \< 0.05); heart rates of NI WB calves were above baseline in only 2 intervals post-disbudding (P \< 0.01), MIN LID calves in 3 intervals (P \< 0.05) and MIN DU calves in 1 interval (P \< 0.05). Cortisol concentrations of DU calves (100.40 pg/mL) were higher (P \< 0.05) than WB calves (88.37 pg/mL); neither DU nor WB differed from LID. Overall, DU and WB offered little to no analgesic effect. These results highlight the need for continued research on organic methods of pain mitigation. Can willow bark or Dull-It provide pain relief in disbudded dairy calves under organic management? Disbudding is a standard procedure on most dairy farms, but organic options to alleviate pain are limited. White willow bark (WB) is commonly used to reduce pain in dairy calves under organic management. Dull It (DU) is a tincture of organic alcohol, apple cider vinegar, WB, St. John\'s Wort, chamomile, arnica, and fennel. The objective of this study was to assess the analgesic effects of oral WB and DU on the heart rates, salivary cortisol concentration, and lying behavior of disbudded Holstein and crossbred dairy calves. Calves were disbudded with a hot iron between 5 to 7 weeks of age (Mean

= 44 d) and randomly assigned to 1 of 3 treatments: Lidocaine only (LID; n=18), Lidocaine and DU (n=18), or Lidocaine and WB (n=17). Heart rates and lying behavior were recorded continuously during the study period. Saliva samples were collected from 30 randomly selected \"minimally-invasive\" (MIN) calves 1 hour before disbudding, at disbudding, 5 min, 10 min, and every 30 min until 240 min after disbudding; the remaining 23 calves served as a \"non-invasive\" (NI) group to control for stress from repeated sampling. Results were analyzed with the fixed effects of treatment, group (NI or MIN), time, and the interactions of treatment, group, and time, with calf as a random effect. There was no main effect of treatment on heart rate, cortisol concentrations, or lying behavior. The heart rates of MIN WB calves were above baseline in 30 (of 48) 5-min intervals post-disbudding; heart rates of NI WB calves were above baseline in only 2 intervals post-disbudding, MIN LID calves in 3 intervals and MIN DU calves in 1 interval. Cortisol concentrations of DU calves (100.40 pg/mL) were higher than WB calves (88.37 pg/mL); neither DU nor WB differed from LID. Overall, DU and WB offered little to no analgesic effect. These results highlight the need for continued research on organic methods of pain mitigation. Publications Type: Other Status: Accepted Year Published: 2023 Citation: UMN Extension Moos Room Podcast - Mar 20, 2023 Episode 162 - UMN WCROC Dairy research update with Dr. Bradley J Heins Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: Addressing Disbudding Pain and Alternative Options for Transitioning Organic Dairy Farms. ORG-PD Meeting, Washington DC, April 2023 Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: Putting Organic Dairy Research to Work - Minnesota Organic Conference, January 6, 2023, St. Cloud, MN Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: M. Bacon, M. Endres, B. Heins. Effects of willow bark (Salix) on post-disbudding behaviors in dairy calves under organic management. J. Dairy Sci. Vol. 106, Suppl. 1, Abstract 1307T, p.306 Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: M. Bacon. Can willow bark or Dull-It provide pain relief in disbudded dairy calves under organic management? UMN CFANS Graduate Research Symposium, March 16, 2023, St. Paul, MN Type: Conference Papers and Presentations Status: Accepted Year Published: 2023 Citation: M. Bacon, M. Endres, B. Heins.Effects of multimodal pain relief on stress in disbudded dairy calves under organic management. Marbleseed Organic Conference. Feb 23-25, 2023, LaCrosse, WI **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:We have reached organic dairy farmers across the Midwest and all of the United States. We have also provided information from the project to veterinarians, organic dairy industry representatives across the United States on the disbudding project. A field day was offered for organic dairy producers, extension educators, and organic industry personnel during August 2022. We have also trained 4 undergraduate and a graduate student in experimental design and collection of research data. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project has trained organic dairy producers on the alternatives for pain mitigation strategies in organic dairy calves. Many extension educators and organic industry representatives were informed on dairy calf disbudding practices at the University of Minnesota organic dairy field day in August 2022. We have trained 4 undergraduate students on how to conduct research and outreach with disbudding and dairy calves. We have also trained a graduate students in proper experiemental design, data collection, and analysis of data. Graduate stduents from Minnesota presented research on 2 disbudding studies at the American Dairy Science Association meeting in June 2022 in Kansas City, Missouri. Results from the study were also presented in poster format at the February 2022 MOSES Organic Conference in LaCrosse, WI. How have the results been disseminated to communities of interest?We hadan in-person organic dairy day at the University of Minnesota West Central Research and Outreach Center in August 2022 to provide farmers and other industry personnel tools that they can take back to their farm when implementing a disbudding program. During the last year, over 250 people have attended the field days at the WCROC. Over 500people have attended presentations related to the objective research in the project. Results were disseminated to academic and audiences through peer-reviewed publications and abstracts presented at conferences. Presentations were also given that included farmers that have used our research results at grazing and organic conferences. What do you plan to do during the next reporting period to accomplish the goals?The investigators and students working on the project continue to review objectives and accomplishments of the project. We have completed a 2 disbudding trials during 2021 and 2022 and a graduate student is currently writing those manuscripts for peer-reviewed publication. We have started a Qualitative Behaviour Assessment with calf disbudding that will continue this year. We are also drafting protocols for behavior for when these calves with horns and disbudded calves enter the milking herd in Spring 2023. Abstracts and further peer-reviewed publications will be drafted in the next year. **Impacts** What was accomplished under these goals? Effects of oral white willow bark (Salix alba) and intravenous flunixin meglumine on prostaglandin E2 in healthy dairy calves. White willow bark (WWB) is commonly used in combination with other medicinal herbs and analgesics to alleviate inflammatory pain in disbudded calves under organic management, but there is no evidence to confirm an effect of WWB on inflammatory biomarkers in calves. The objective of this study was to determine whether WWB affects the inflammatory biomarker prostaglandin E2 (PGE2) in healthy dairy calves. A randomized crossover trial with 2 periods and 5 treatments was used for this experiment. A 7-d washout period was used to minimize carryover effects. The treatments were (1) 57.6 mg/kg oral WWB (low dose; L-WWB), (2) 115.1 mg/kg oral WWB (medium dose; M-WWB), (3) 230.3 mg/kg oral WWB (high dose; H-WWB), (4) 2.2 mg/kg i.v. flunixin meglumine (FM), or (5) no treatment (NT). Calves (n = 25) were randomly assigned to receive 1 of the 25 treatment sequences. Blood samples were collected at 1, 2, and 4 h after administration to determine PGE2 and salicylic acid plasma concentrations. The WWB had 2,171 μg/g (± 4.3% relative standard error) salicin (0.22%). On average, calves in the FM (721 ± 274 pg/mL) treatment had lower PGE2 than calves in all other treatments. Calves in the NT (2,606 ± 271 pg/mL), L-WWB (2,509 ± 276 pg/mL), M-WWB (2,343 ± 270 pg/mL), and H-WWB (3,039 ± 270 pg/mL) treatments had similar PGE2 averaged across sampling times. Calves in the L-WWB (23.4 ± 1.9 ng/mL), M-WWB (21.5 ± 1.9 ng/mL), and H-WWB (23.3 ± 1.9 ng/mL) treatments had similar maximum salicylic acid plasma concentrations. Results from this study indicate that the WWB doses used in this experiment were ineffective at achieving dose-dependent PGE2 and salicylic acid plasma concentration responses. Effects of multimodal pain relief on stress in disbudded dairy calves under organic management.Disbudding is a standard procedure on most dairy farms, but organic options to alleviate pain are limited. White willow bark (WB) is commonly used to reduce pain in dairy calves under organic management. Dull It (DU) is a tincture of organic alcohol, apple cider vinegar, WB, St. John's Wort, chamomile, arnica, and fennel. The objective of this study was to assess the analgesic effects of oral WB and DU on the heart rates, salivary cortisol concentration, and lying behavior of disbudded Holstein and crossbred dairy calves. Calves were disbudded with a hot iron between 5 to 7 weeks of age (Mean = 44 d) and randomly assigned to 1 of 3 treatments: Lidocaine only (LID; n = 18), Lidocaine and DU (n = 18), or Lidocaine and WB (n = 17). Polar H10 monitors recorded heart rates continuously during the 5-h study period; readings were averaged in 5-min intervals. HOBO loggers recorded lying behavior during the study and the following 3 d in 1-min intervals. Saliva samples were collected from 30 randomly selected \"minimally-invasive\" (MIN) calves 1 h before disbudding, at the time of disbudding, 5 min, 10 min, and every 30 min until 240 min after disbudding; the remaining 23 calves served as a \"non-invasive\" (NI) group to control for stress from repeated sampling. Results were analyzed with the fixed effects of treatment, group (NI or MIN), time, and the interactions of treatment, group, and time, with calf as a random effect. There was no main effect of treatment on heart rate or cortisol concentrations. The heart rates of MIN WB calves were above baseline in 30 (of 48) 5-min intervals post-disbudding; by comparison, heart rates of NI WB calves were above baseline in only 2 intervals post-disbudding, MIN LID calves were above baseline in 3 intervalsand MIN DU calves were above baseline in 1 interval. Cortisol concentrations of DU calves (100.40 pg/mL) were higherthan WB calves (88.37 pg/mL); neither DU nor WB differed from LID. There was no difference in lyingbehavior between treatments. These findings indicate that DU and WB offer little to no analgesic effect. Effects of willow bark (Salix) on pain and stress in recently disbudded organic dairy calves.White Willow Bark (Salix) is commonly used to alleviate pain in disbudded calves under organic management, but there is no scientific evidence that willow bark (WB) has an analgesic effect in cattle. The objective of this study was to evaluate the effect of an oral WB bolus on heart rate, salivary cortisol, ocular temperature, and lying behavior of 42 Holstein and crossbred heifer calves disbudded between 4 to 7 weeks of age (Mean = 42 d). Calves (n = 14 calves per treatment) were randomly assigned to 1 of 3 treatments: hot-iron disbudding with lidocaine (5 mL per horn bud), hot-iron disbudding with oral WB (200 mg/kg), or a cold iron \"sham\" disbudding. Thermal images of the eye and saliva sampleswere collected 1 h before disbudding, at the time of disbudding, 5 min, 10 min, and every 30 min until 240 min after disbudding. Polar H10 heart rate monitors recorded heartrates continuously throughout the 5-h study period; readings were analyzed in 5-min intervals. HOBO loggers recorded lying behavior during the study period and the following 2 d in 1-min intervals. Results were analyzed with the fixed effects of treatment, time within the study, and the interactions of treatment and time, with calf as a random effect. The mean heart rate of sham calves was lower than both lidocaine (P < 0.05) and WB calves (P < 0.001) by 11.44 ± 4.13 bpm and 14.71 ± 4.21 bpm, respectively. The WB calves' heart rates were 11.64 ± 5.78 bpm higher than lidocaine calves during the 5 min immediately following disbudding and 17.00 ± 5.72 bpm higher during the next 5 min. Salivary cortisol concentrations were higher in lidocaine calves (98.93 pg/mL) and WB calves (108.03 pg/mL) than sham calves (87.44 pg/ mL). Cortisol peaked 90 min after disbudding in WB calves (146.161 pg/mL) and 120 min after disbudding in lidocaine calves (121.98 pg/mL). No differences were observed for ocular temperature or lying time or bouts. These results indicate that neither WB nor lidocaine alone are sufficient for relieving disbudding-related pain in dairy calves. **Publications** - Type: Journal Articles Status: Accepted Year Published: 2022 Citation: Effects of oral white willow bark (Salix alba) and intravenous flunixin meglumine on prostaglandin E2 in healthy dairy calves Phillips, H.N. et al. JDS Communications, Volume 3, Issue 1, 49 - 54 https://www.jdscommun.org/article/S2666-9102(21)00164-2/fulltext - Type: Journal Articles Status: Accepted Year Published: 2022 Citation: Phillips, H.N.; Heins, B.J. Alternative Practices in Organic Dairy Production and Effects on Animal Behavior, Health, and Welfare. Animals 2022, 12, 1785. https://doi.org/10.3390/ani12141785 - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Bacon, M, M. Endres, and B.J. Heins. 2022. Effects?of?multimodal?pain?relief?on?stress?in?disbudded dairy calves under organic management. Abstract #1324. J. Dairy Sci. Vol. 105, Suppl. 1. Page 128. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Bacon, M, M. Endres, and B.J. Heins. 2022.

Effects?of?willow?bark?(Salix) on pain and stress in recently disbudded organic dairy calves. Abstract #1326. J. Dairy Sci. Vol. 105, Suppl. 1. Page 128-129. - Type: Other Status: Published Year Published: 2022 Citation: Heins, Brad. 2022. Organic Dairy Research News. University of Minnesota. July 2022. 8 pages - Type: Other Status: Published Year Published: 2022 Citation: The MOOS Room Podcast. Brad Heins and Extension colleagues are the hosts of a dairy and beef podcast where we discuss dairy issues and organic dairy production are a focus of some of the podcasts. Find on Google Podcasts, IheartRadio, and Apple Podcasts.

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Understanding and Overcoming Barriers to Adoption of Organic Agriculture in the Mid-south

Accession No.	1023608
Project No.	MO00070309
Agency	NIFA MO.\
Project Type	OTHER GRANTS
Project Status	NEW
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Proposal No.	2020-02285
Start Date	01 SEP 2020
Term Date	31 AUG 2023
Grant Amount	$422,307
Grant Year	2020
Investigator(s)	Hendrickson, M. K.

NON-TECHNICAL SUMMARY

Disproportionate adoption of USDA Certified Organic Production has left certified producer numbers lower in the Lower Midwest and Mid-South than in other regions of the country such as the Upper Midwest, West Coast, or Northeastern US. These clusters suggest regional characteristics impact adoption of organic agriculture. An interdisciplinary team proposes an integrated project to examine the following: the biophysical, market and cultural barriers to organic production in the Mid-South; the region-specific opportunities and farmer-led innovations present, and what support is needed; and state-level policies to increase the region\'s number of organic farmers and expand production. The project will also identify region-specific barriers and opportunities to organic production, and examine the effects of policy supports for organic farming. Findings will inform outreach that builds educator skills to support organic producers and strengthen emerging organic farmer networks. Specific objectives include: 1) identifying region-specific barriers to organic adoption; 2) identifying region-specific opportunities and farmer-led innovations to increase organic operations and acreage; 3) analysing impacts of potential state-level public policy; 4) implementing an outreach program for farmers and educators addressing specific challenges and opportunities; and 5) supporting networks of organic producers in peer-to-peer learning, collectively securing inputs, and pursuing new markets. In-person interviews of 75 current and former certified organic farmers will identify barriers and opportunities. Results will inform educator training to prepare them to support organic farmers and farmer networks. Policy analysis will quantify the impacts of potential regional policies. Research results will be presented at regional extension/farmer meetings as well as academic conferences. Expected outcomes of increased understanding of barriers to organic adoption, expanded membership in organic producer networks, and better understanding of needed policy and market interventions will lead to agricultural sustainability and profitability in the region.

OBJECTIVES

The goal of this research is to identify adoption challenges specific to the Mid-South, and to offer insights about specific policy supports, agricultural research, organic processing infrastructure development, and market development needed in the region. By identifying and better understanding these challenges, extension, university, and governmental agencies will be better equipped to serve producers in the region. The specific objectives of this project are:Research Objectives:To identify region-specific economic, social and biophysical barriers to USDA Certified Organic adoption in the Mid-South, a region including parts of Missouri, Oklahoma, Arkansas, and Tennessee; To identify region-specific opportunities and farmer-led innovations that could increase USDA Certified Organic farm numbers and acreage;To identify public policy measures that have impacted organic adoption in other regions and explore their feasibility for the Mid-SouthExtension Objectives:To develop and implement an outreach program for farmers and educators addressing specific challenges and opportunities identified by this research;To support new, and strengthen emerging, networks of producers that can support peer-to-peer learning, develop collective methods to secure inputs, and pursue marketing opportunities.

APPROACH

Approach and Methods:Objective 1: To identify region-specific economic, social and biophysical barriers to USDA Certified Organic adoption in the Mid-South, a region including parts of Missouri, Arkansas, Oklahoma, and Tennessee;Objective 2: To identify region-specific opportunities and farmer-led innovations that could increase USDA Certified Organic farm numbers and acreage;We will conduct 75 semi-structured interviews with current and lapsed certified organic producers who are located within southern MO, western TN, northern AR and eastern OK. Using the list of currently certified and formerly certified organic growers in the online USDA database of organically certified growers, we will draw a sample that will include a variety of farm sizes, locations and products produced. We will try to pair interviews of lapsed and currently certified farmers in locations, sizes and products produced. The interview protocol will include questions regarding a) biophysical barriers to producing organically; b) perceptions of regional access to markets and infrastructure; c) perception of cultural attitudes about organic production; d) sources of information and support for organic farming; and e) new opportunities that are emerging for their farm operation. Lapsed organic growers will provide a contrasting perspective about the value of certification and of organic production. Face-to-face interviews will be transcribed and qualitatively analyzed using NVivo software, coding first for emergent themes, and recoding by theoretical category. Objective 3: To identify public policy measures that have impacted organic adoption in other regions and explore their feasibility for the Mid-South. To meet Objective 3, we will compile state-level organic policies, certification processes, and other state support programs through policy searches conducted through the Thomson Reuters Westlaw legal research database, complimented by phone interviews with state agriculture personnel responsible for alternative markets, state extension specialists supporting local, sustainable and organic production, and leaders in organic grower and land stewardship organizations. We will focus on at least 4-5 states with larger grower numbers as well as our target states. We will qualitatively analyze the information collected in this phase to examine nuances in state policies, how the organic certification process is implemented in the state, availability of support programs to educate producers or to provide cost-shares, and other issues that emerge in terms of how they affect organic farm revenues and expenses.In the quantitative phase of this project, the policies and processes will be translated into their economic impacts on organic farm revenues and expenses for each state. Based on USDA data of organic prices, costs of production, crop area involved in production and yields cross-checked with our participating farmers, organic farm enterprise budgets will be constructed to illustrate how different policies, processes, and support programs impact revenues, expenses, and net farm income by state. These budgets will be compared with actual reported organic farm enterprise budgets from the FINBIN database (maintained by the University of Minnesota https://finbin.umn.edu/). In addition, organic prices will be compiled from USDA\'s Agricultural Marketing Service database. Comparing organic prices across states will provide insight about the demand for organic production in each state. The results obtained from the quantitative analysis will provide insight into how policies, certification processes, and other support programs can be modified in the Mid-South to be more conducive to organic production. Objective 4: To develop and implement an outreach program for farmers and educators addressing specific challenges and opportunities identified by this research; Two distinct kinds of activities will be used to achieve Objective 4; targeted training for extension and other educators, and incorporation of research results into on-going training in the University of Missouri\'s Organic outreach program and Kerr Center\'s on-going outreach. First, using results from the interviews and the policy analysis, we will plan a 1.5-day training opportunity in the second half of Year 2 for 30 regional Extension educators, non-profit personnel and organic producers. The training will be modular with half-day programming sessions oriented to horticultural crops, grain crops and livestock to allow for greater participation from educators with limited time. The goal of this training is to build the capacities of educators and farmer leaders to understand barriers to adoption of organic in the Mid-South in order to better assist producers and communities both in identifying potential organic opportunities as well as strategies for organic management in a changing climate. In addition, the preliminary results of the policy analysis will be presented so that educators and farmer leaders can inform policy makers of potential impacts of state level organic policy. This workshop will help educators develop programming that can provide ongoing support for emerging organic networks. A second set of activities will be conducted through the Kerr Center\'s existing outreach program, MU\'s Organic outreach program, as well as through Missouri\'s Agriculture Business and Policy extension program. This will include:Research results presented at annual MU Organic Field Days held at farms of research collaborators and farmer network members.Research results incorporated into existing Kerr Center and MU workshops/conferences/meetings.Research results fed into the MU Twitter feed, which reaches thousands in the state.A presentation on identifying barriers and opportunities at the Mid-America Organic Association (MOA) and SSAWG conferences.Quantitative policy analysis results including organic production budgets, the costs of converting to organic production, as well as other organic production issues will be added as module to the \"value added\" program in Missouri\'s Agricultural Business and Policy Extension outreach. Objective 5: To support new, and strengthen emerging, networks of producers that can support peer-to-peer learning, develop collective methods to secure inputs, and pursue marketing opportunities.We will use a small mini-grant program to support the development or expansion of networks of organic producers in the region (eastern OK, southern MO, western TN, northern AR) which will be coordinated by the Kerr Center. As coordinator of the southern region SARE PDP, Kerr Center has experience in managing a grant program, with the ability to facilitate paperwork for farmer groups who wish to apply. We plan to provide \$7,500/year in Years 2 and 3 to between 3-5 producer groups to allow them to engage in peer-to-peer learning opportunities (e.g. informal field days, online collaboration and training, mentoring, social activities oriented to learning new organic techniques), OR to collaborate in collectively acquiring inputs or pursuing marketing opportunities. During the first three months of the project, the project team will agree upon criteria for the grant program, using regional SARE producer grant criteria to guide the process, as well as establish the application protocol. Grants will be capped at \$3,000 per group per year. Grants will be publicized through extension and existing organic producer networks, as well as to eligible producers at the at the 2021 and 2022 SSAWG and MOA winter meetings. Grants will be awarded in the first month of Years 1 and 2 (September) for completion within the year. A network representative of each grantee will be encouraged to discuss the results of their mini-grant activities at field days and/or MOA/SSAWG conferences. Progress 09/01/23 to 08/31/24 Outputs Target Audience:The main target audience is the organic sector in the Mid-South, which includes farm-level production and supply chain actors such as input suppliers, processors, buyers and aggregators. The most important audience is farmers and agricultural educators such as extension educators, federal and state agency personnel, non-profit staff and land-grant extension administrators. Changes/Problems: Policy Research: We had difficulty securing interviews with policy decision-makers in state agencies or with agricultural gropus with policy agendas in the Mid-South given the dearth of existing state-level organic policies in these states. We finally secured two interviews with each state after patiently explaining that we were interested in talking with agency officials even if these did not have any organic-specific policies. Because of the absence of state-level policies, we were unable to secure enough information for a quantiative policy analysis where we could compare organic farm enterprise budgets. We have changed this to focus on developing these budgets for the Mid-South and comparing with other available budgets. Primary Producer Research: Given the emerging themes of gendered perspectives in organic agriculture, we have re-interviewed five initial participants and added two more organic women producers. This sheds light on unique challenges that women face in organic production in this area. What opportunities for training and professional development has the project provided?Graduate Student Education: During this year of the project, GRA Srivastava further improved her qualitative coding and analysis skills as well as project management skills. In addition, she completed her comprehensive examinations where she proposed re-analysing the data from this project with a gendered perspective, as well as including additional interviews with women organic farmers and organic adjacent farming styles. This interest grew out of analyzing project findings which showed interesting gendered perspectives in our data. The project supported her additional interviews with organic farmers in summer 2024. Post-Doctoral Training: Stephen Mukembo, post-doc in Division of Appied Social Sciences interested in innovatino and entrperneurship worked with our project data and became lead author on a manuscript (accepted in early summer 2024) for Journal of Agriculture, Food Systems and Community Development. In addition, he co-mentored Srivastava on developing and writing manuscripts with Hendrickson. How have the results been disseminated to communities of interest?The preliminary results of our project have been presented at the Rural Sociological Society annual meetings. In addition, we developed a poster specifically for presentation at the Missouri Organi Association (MOA) annual meeting. It was prominently displayed by the registration and receoption area. Hendrickson met with key MOA personnel who are organizing aspects of the TOPP program in Missouri. We supplied key contact information for extension educators and worked to collaboratively develop our extension series with them. Disseminating the results of our projects to edcators and other interested audiences began in earnest with our webinar series that kicked off on August 22, 2024. In addition to participants, the video recording was distributed through the Kerr Center newsletter, the Center for Arkansas Food and Farms at U of Arkansas, and the food systems network with U of Missouri extension. What do you plan to do during the next reporting period to accomplish the goals?Research Objectives: Draft organic egg layer and grain budgets will be refined through representative producer panels who judge the accuracy of the budget and suggest changes. These budgets will then be used for policy and education outreach. Finish final analysis of research data and prepare additional manuscripts. Report of the state of organic in the Mid-South and findings from our research and their implications will be finalized in December 2024 for distribution to extension administrators and state agency personnel. (It will also be avialable generally with a DOI specific identifier.) Additional manuscripts (\~2) will be drafted and submitted. Extension Objectives: Finish the extension educator series. Webinars are scheduled for October 2024 (What is TOPP?), December 2024 (What can federal agencies offer your organic producers), early February (Tips for Working with organic producers from those who do); March 2025 (Organic budgets for the Mid-South); and early April 2025 (two in-person field trips organized for extension educators to see their organic work in action). All webinars have been or will be recorded and when the series if finalized will be publicly available through a University of Missouri extension website. Impacts What was accomplished under these goals? RESEARCH OBJECTIVES: Important Findings from the project include: Farmers motivations for organic production differ according to types of operations, for grain producers the main motivation is markets, for egg producers health concerns and operations that fit with their lifestyle motivated them to organic, while environmental concerns topped the list for diversified vegetable/small livestock producers. Biophysical barriers are important: 80% of vegetable producers, 75% of grain producers and 50% of egg producers specified at least one biophysical barrier, where weather was more severe issues with vegetable growers, soil fertility with grain growers, and predators with egg layer operations. Still these barriers are perceived to be manageable. Markets, certification and infrastructure are perceived as more difficult challenges than biophysical barriers across operation types. Fertilizer was a big issue in 2022 as conventional farmers substituted poultry litter for conventional fertilizer. Demand is important for diversfied vegetable producers. Our Journal of Agriculture, Food Systems and Community Development article explored how farmers in this area navigated these challenges and innovated to solve them. Some producers feel like the culture of their rural areas does not support organic, and many feel that they receive little support among federal and state agency personnel and extension educators. Results from our initial policy analysis shows there is little awareness of organic agricuture in these states or support for organic agriculture compared to other states in the Upper Midwest. MAIN FINDING: To increase organic production in this area we need to build on the innovative approaches that farmers are taking while building an ecosystem of support for organic producers. This ecosystem would include: Building human capital through training and collaborations; expanding and improving market access; encouraging asupportive policy environment; providing better access to financing, and helping to increase community support for organic. On-going research in policy: we developed a draft organic budget template for organic egg laying operations and organic corn and soybean operations in the Mid-South. This will be further refined and tested in the final year of the project. EXTENSION OBJECTIVES: We developed and initiated a extension and professional agricutlural educator webinar series starting August, 2024. The series consists of 5 webinars and 1 in-person field trip (two opportunities for field trips). The first series was delivered on August 22, 2024 and showcased the research findings of the project in addition to providing information about the state of organic in the Mid-South. Between August 22, 2024 and April 30, 2025, an additional 4 webinars and 1 field trip will be held. In addition we have distributed more mini-grants to producers in Missouri, Oklahoma and Arkansas. Besides publicizing the availability of mini-grants through organizations such as the Missouri Organic Association, Kerr Center and extension services for MO, AR and OK, we mailed a flyer with information about the grants to nearly 500 organic producers in our target area. We have generated interest and have been able to support farmer-led organic field days, farmer-led and identified education, and farmer-ed networking. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Srivastava, G., M. Hendrickson and K. Wilson. 2024. \"Gender Perspectives in Organic Farming in the Mid-South Region:Motivation, Challenges and Opportunities.\" Annual meeting of the Rural Sociological Society. July 24-28. Madison, WI. Type: Other Status: Published Year Published: 2024 Citation: Hendrickson, M. D. Redhage, G.Srivastava and K. Clark. 2024. Understanding and Overcoming Barriers to Adoption of Organic Agriculture in the Mid-South. Poster presentation at Missouri Organic Association annual meeting. Hartsburg, MO. February. Progress 09/01/22 to 08/31/23 Outputs Target Audience:University of Missouri Extension educators interested in alternative food networks - sharing research information with them to prepare them to best serve organic farmers in the state. Undergraduate students at the University of Missouri interested in alternative agriculture - sharing research information with them to help them understand the challenges and motivations of organic farmers in this area. Changes/Problems: Interviews have been exceeding difficult to secure with relevant policy personnel in MO, AR and TN. We are trying to finish those interviews as soon as possible. We had to ask an external consultant to check code some of our data analysis to validate our findings. We have been unable to distribute as many mini-grants as budgeted and are hoping to do another round of networking with farmers to make them aware of the possibility for funds. What opportunities for training and professional development has the project provided? Provided information on organic farming and presented research findings from our project to 25 extension educators through the University of Missouri Extension Food Systems Network monthly webinars on December 7, 2022. In addition, the graduate student supported by the project has attended 2 Rural Sociological Society meetings, and a Southern Rural Sociological Association meeting which has provided additional professional development opportunities. How have the results been disseminated to communities of interest? Prelminary results have been presented through research posters and conference presentations to the academic community of rural sociologists at two academic conferences, and have been presented through a poster for approximately 100 students and faculty at the MU College of Agriculture, Food & Natural Resources. David Redhage, Co-PI, attended PI meeting in April,

2023. During this time he made connections with Patrick Baur at University of Rhode Island to whom we\'ve reached out and shared information and ideas for further research. What do you plan to do during the next reporting period to accomplish the goals?For Research Objectives 1-3: Finish data analysis of farmer interviews and work on three manuscripts for peer-reviewed journals, including: Submission of a manuscript toJournal of Agriculture, Food Systems and Community Developmenton innovation in response to identified challenges. Submission planned for December, 2023. Development of manuscript examining the challenges and opportunities of this particular region, paying particular attention to how the challenges are udnerstood by farmers and shape opportunities. Development of manuscript focused primarily on those who surrendered certificaiton on all or part of thier operations. Finish coding and analysis of policy interviews and conduct2 more interviews with state agency personnel (MO & AR) For Extension Objectives 1&2: Distribute mini-grants to farmer groups in Winter 2023-2024 Prepare and conduct hybrid extension training including webinars and regional field trips (SW MO, SE MO/TN, AR/OK) Compile report and recommendations for Extension administrators on the needs for extension training and technical assistance in the region. Impacts What was accomplished under these goals? Accomplishments 22-23 on Research Objectives 1-2: We added 5more farmer interviews, so that we have now conducted a total of 40 interviews with 49 participants who are organic farmers or processors across the regions included in the project. These included 9 intervews where the organic farmers have surrendered their certification on all or parts of their operations. During this project period we finished transcribing interviews that were conducted, and began qualitative coding of the transcriptions. We provided 20 de-identified transcriptions to an external coder familiar with organic farming in the region to check our coding. We then developed themes from these codes and wrote research memos. These served as the basis for the three presentations at academic conferences showcasing preliminary findings. Themes and findings that have emerged in preliminary analysis include: Biophysical barriers such as pests, soil fertility, weeds, and weather are important challenges to organic farmers in this region but are considered manageable. In other words, while they are significant challenges and require innovation and experimentation to overcome, they do not seem to block adoption. Organic farmers face increased competition from conventional farmers for inputs, particularly for those such as poultry litter. Farmers desribe lack of availabity, increased prices for liter, and lack of transport for this product which in prior times had been relatively abundant and inexpensive. Some direct-market farmers or farmers oriented to sales of value-added products described a lack of education among the region\'s consumers about what organic is, and perceived that consumers do not always trust the label.Farmers described that the lack of proper infrastructure and inputs to support organic production has led to higher production costs, resulting in higher prices for organic products, which many rural consumers cannot afford. While access to markets and infrastructure is an important challenge, it can also provide new opportunities to diversify operations or establish new entities such as feed mills or input supply stores. Producers evolved innovations that addressed some of their challenges, but it is important to note that innovations require ecosystems in which to embed Policy barriers for organic farmers include accessing FSA loans and opportunities, as well as difficulty in dealing with drift (especially in Mississippi Delta area of our study region) For over half of the farmers surrendering certification on all or part of the operation, it was involuntary due to contamination from neighboring farms (spray drift) or lack of access to markets (dairy producers). Only a couple of farmer surrendered certification on their entire operation. Accomplishments 22-23 on Research Objectives 3: We have conducted 6 interviews concerned with public policy in MO, OK, MN (2) and GA. These interviews have been hard to nail down. We are currently transcribing and analyzing these interviews. Accomplishments 22-23 on Extension Objectives 1-2: We provided our preliminary research findings and information on organic policies to the University of Missouri Extension Food Systems Networking team at their December, 2022 meeting. Utilizing feedback and connections from that presentation, we have developed an outline and plan for extension trainings to take place in a hybrid fashion in the Spring and Summer of 2024. This will consist of online seminars and field trips to existing farms and infrastructure during the summer. Kerr Center has networked organic farmers in northern Arkansas and eastern Oklahoma together as well as provided resource and information. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Srivastava, Garima, Stephen C. Mukembo, Mary Hendrickson, David Redhage, and Kerry Clark.2023. \"Increasing Resilient Organic Production in the Mid-South Region.\" Paper presented at the Southern Rural Sociological Association Annual Meeting. Oklahoma City, OK.February. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Srivastava, Garima, Mary Hendrickson and Stephen Mukembo. 2023. A Phenomenological Inquiry into Organic Producers\' Experiences in Surrendering Certification in the Mid-South. Paper presented at the Rural Sociological Societys annual meeting. Burlington, VT. August 2-6. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Srivastava, Garima, Mary Hendrickson, David Redhage and Kerry Clark. 2022.\"Why is there an Organic Cold Spot in the Mid-South? Opportunities and Challenges for Organic Farmers in this Region.\" Poster presented at University of Missouri College of Agriculture, Food and Natural Resources Research Symposium. Columbia, MO. October 12. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:During this year's work, we reached the following audiences: 45 organic and transitioning row crop farmers attended a day long workshop on weed management and control in row crops 20 graduate students and researchers attended a session where we reported preliminary results from our interviews with organic farmers. Changes/Problems:In general the interviews have been much slower to happen, first because of Covid (in first project period) and we are trying to play catch-up. It has been more difficult than anticipated to find and schedule interviews, particularly with farmers who are doing egg production. In addition, we are planning to do some more surrendered certification farmers to find out what challenges they encountered. (To date, dairy has been an extermely touchy subject with Missouri farmers, with some farmers surrending their certificaiton on their dairy cows but keeping it with their grain crops.) In the next project period, we are considering finding additional research help for data analysis and contributions to research publications. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals? In our next reporting period we will be finishing analysis of interviews with farmers and with policy advocates and agency personnel so we will be able to share our analysis with extension educators and farmer organizations. In addition, we are currently planning outreach to extension services in our four state region that should begin next project period. **Impacts** What was accomplished under these goals? Goal 1: To identify region-specific economic, social and biophysical barriers to USDA Certified Organic adoption in the Mid-South, a region including parts of Missouri, Oklahoma, Arkansas, and Tennessee; Goal 2: To identify region-specific opportunities and farmer-led innovations that could increase USDA Certified Organic farm numbers and acreage; For these first two goals we have identified and interviewed 37 farmers and processors scattered across all states included in the project. During this project period we transcribed the interviews that were conducted, and are beginning qualitative analysis of the interviews. Themes that have emerged in preliminary analysis include: biophysical barriers such as pests, soil fertility, weeds, and weather are important challenges to organic farmers in this region. They vary across sectors (e.g. weather was more severe issues with vegetable growers, soil fertility with grain growers, predators with egg layers), but they are often considered manageable by the farmers. soil fertility has often been managed in this region by acquiring poultry litter from widespread conventional poultry operations. In fall 2021 and early 2022, farmers complained of the difficulty and expense of obtaining this valuable input given the competition from conventional farmers. The latter had switched to poultry litter given the high prices of conventional fertilizer. Infrastructure challenges such as finding inputs and finding markets remains a key issue in this area. Vegetable growers selling directly emphasized the difficulty of saturated markets for organic produce, while grain growers emphasized need for inputs and more accessible organic mills or elevators. Across the board farmers are facing labor challenges (both on farm and for transportation) and access to organic inputs. This however can be considered opportunity as well. Certification process can be intimidating, and availability is uneven (accessing certifiers seemed to be more of an issue in northern Arkansas). Howeveer, farmers found that record-keeping was helpful for their farm management too. We also interviewed farmers who had found new opportunities such as the growth of egg layers as a important business for farmers in this region, as well as for processors and input suppliers. Many farmers entering organic production in this area, especially in grain growing, are motivated by better prices for crops or better profits per acre for farms that are constrained by land availability (such as in certain areas with many Plain People). Goal 3: To identify public policy measures that have impacted organic adoption in other regions and explore their feasibility for the Mid-South We identified the key states we wanted to compare by searching for organic policies and statues. The states identified are Minnesota, Georgia, Wisconsin, Texas and possibly North Carolina. Extension objectives have not yet been undertaken. **Publications** - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Srivastava, Garima, Mary K. Hendrickson, David Redhage and Kerry Clark. 2022. Why is there an organic Coldspot in the Mid-South? Opportunities and Challenges for organic farmers in this region.Paper presented at the Rural Sociological Societys annual meeting. Denver, CO. August 4-7. **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience: Nothing Reported Changes/Problems:No major changes in approach, but some timeline changes. Covid restrictions on travel did not loosen until March 2021 at our University and delayed our ability to interview farmers during the winter season. We have conducted some virtual interviews but the on-farm visits are superior. We are busy catching up with the interviews. Based on a few initial intervies, we are expanding how we will give small grants to groups of farmers. We are likely to work with specific individuals who will be able to coordinate activities for farmers given time constraints of farmers. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals?Research Objectives: Finish interviews with organic farmers and analyze results. We also will finish coding the policies we have collected and initiate interviews with selected state level non-profit and government officials. Extension Objectives: Roll out small grants program for farmers. **Impacts** What was accomplished under these goals? Research Objectives: We are in the research phase where we are conducting interviews with identified organic farmers in our region. We have begun collection of organic policies from state considered organic hotspots. Extension Objectives: We have initiated contacts with non-profit organizations in our region. We have developed criteria for our small grant program based on a few initial interviews. **Publications**

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A Biobased Mulch Innovation for Organic Spinach and Carrots

Accession No.	1023776
Project No.	NEB-22-408
Agency	NIFA NEB\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51106-32380
Proposal No.	2020-02364
Start Date	01 SEP 2020
Term Date	31 AUG 2023
Grant Amount	$475,000
Grant Year	2020
Investigator(s)	Wortman, S.

NON-TECHNICAL SUMMARY

Biobased mulch (biomulch) is a useful organic weed management tool, but is not typically used for high-density, direct-seeded vegetable plantings like spinach and carrot. Instead, hand weeding is common in these crops, but the cost and scarcity of labor represents a significant barrier to organic transitions. Our goal is to leverage the unique properties of biomulch to develop and study a novel system where: 1) crops are seeded directly on top of biomulch, 2) top-dressed with compost to facilitate germination, and 3) the biomulch is used to remove crops from the field or left to biodegrade. In addition to improved weed management, we expect that biomulch use could reduce exposure to foodborne pathogens, conserve soil moisture, mitigate extreme root zone temperatures, and increase soil nitrogen (when organic fertilizers are embedded in the biomulch). We will conduct field studies in organic spinach and carrots to: 1) quantify the agronomic performance of six prototype biomulches (varying in materials, weight basis and strength, and biodegradability) and two composts; 2) determine the effect of biomulch and compost on foodborne pathogens in soil and the crop rhizo- and phyllosphere; and 3) estimate profitability of the biomulch system. Project results will be disseminated to organic farmers, researchers, and educators through conferences, webinars, social media, and scientific publications. Broader impacts will be achieved by integrating results into curriculum for a new online course, \"Organic Weed Management Innovations for Specialty Crops,\" which will serve academic and non-academic audiences and includes scholarships for beginning and resource-limited farmers.

OBJECTIVES

This project is framed by three research objectives, one education objective, and one extension objective:Objective 1. Quantify the effects of biomulch properties and compost top-dressings on agronomic performance in organic spinach and carrot production systems, including weed suppression, nitrogen dynamics, soil temperature and moisture, disease incidence, and crop yield.Objective 2. Determine the effect of biomulch and compost top-dressings on foodborne pathogens and fecal indicators in organic spinach and carrots.Objective 3. Perform a partial budget analysis to identify potential labor and cost savings of the proposed biomulch system for organic spinach and carrots.Objective 4. Develop curriculum and teach a new online course for academic and professional audiences titled, \"Organic Weed Management Innovations for Specialty Crops.\"Objective 5. Disseminate project results to current and future organic farmers and researchers.

APPROACH

Objective 1:Experimental design. To accomplish objective 1, field experiments will be conducted on organic research land in eastern Nebraska in project years one and two. Experiments will be conducted in organic spinach and organic carrots, each serving as distinctly different model crops for direct-seeded, high-density vegetable plantings that could benefit from the proposed biomulch innovation. We will use a factorial randomized complete block design with two factors and one control, including:Factor 1: BiomulchTreatment 1: PLA/PBS/soy - 150 gsm (mulch components - weight basis; PLA=polylactic acid, PBS=polybutylene succinate, soy=soybean meal particles);Treatment 2: PLA/PBS/soy - 250 gsm;Treatment 3: PLA/soy - 150 gsm;Treatment 4: PLA/soy - 250 gsm;Treatment 5: PLA - 150 gsm;Treatment 6: PLA - 250 gsm;Treatment 7: No mulchFactor 2: Compost Top-DressingsTreatment 1: Yard waste compost;Treatment 2: Chicken manure compostControl: Typical planting method and organic weed management (tine- and hand-weeding) for spinach and carrots in bare soil without biomulch or compost top-dressings.Sequence of crop management activities. Production activities and schedules for organic spinach and carrots will follow recommendations for the north central U.S. Prior to planting either crop, the field will be rotary-tilled and biomulch treatments laid with a raised bed mulch layer (Nolts RB448; Nolt\'s Produce Supplies, Leola, PA, USA).Spinach and carrots will be planted using a narrow-row, high-density approach that allows for a greater number of seed lines per bed top. This high-density approach is most common for \"baby\" spinach and \"cut-and-peel\" carrot types. Spinach will be seeded at a target rate of 5 million plants/ha with 7.5 cm between rows and 10 rows per bed top. Carrot will be seeded at a target rate of 1.7 million plants/ha with 7.5 cm between rows and 10 rows per bed top. Seeds will be dropped in rows on the biomulch using a modified precision vegetable seeder (JP-3 row seeder, Mechanical Transplanter Co., Holland, MI, USA). Biomulch and seeds will be immediately top-dressed with 0.5 cm (\~13 Mg/ha) of yard waste or chicken manure compost treatments. Crops will be managed thereafter using recommended organic practices for the region, and harvested for yield data as described below. To accomplish project objective 3 (described below), biomulch will either be incorporated in soil or concurrently removed from the field along with harvested crops (depending on treatment). Data collection.Weed suppression: Weed emergence will be counted and categorized as grass or broadleaf every two weeks during crop growth by placing a 0.6 × 0.6 m quadrat in a random location within each plot.Soil nitrogen dynamics: Plant available soil nitrogen will be continuously measured during crop growth using ion exchange resin stakes (PRS Probes; Western Ag Innovations, Saskatoon, Saskatchewan, Canada).Soil moisture and temperature: Point measurements of volumetric soil moisture will be estimated weekly in each plot, and soil temperature will be continuously measured throughout the growing season in each plot.Disease incidence: Incidence and severity of any plant diseases will be scouted weekly and recorded using established disease rating scales.Biomulch deterioration and degradation: Biomulch deterioration during the growing season will be scouted weekly, and all rips, tears, and holes will be counted in each plot. Biomulch degradation will be determined by weighing a 30 × 30 cm swatch of biomulch from each plot at the end of the growing season.Crop yield and quality: Spinach and carrots will be harvested, graded,and weighed fresh.Objective 2:Description and sequence of activities and methods. Experiments for objective 2 will be built around the experimental design described for objective 1. Microbial quality will be assessed before planting and at harvest. Fecal indicators will be quantified from compost and biomulch prior to application, pre-application soils, and amended soils prior to planting; and from soils and vegetables at harvest. E. coli, total coliforms, and enterococci will be enumerated using selective media and the most-probable number technique. E. coli is the classic fecal indicator, although some E. coli can also survive in the environment. The total coliform group includes a broader range of bacteria, including some non-fecal members that are on a watch-list for antibiotic resistance. The enterococci are a group of fecal bacteria that have thick cell walls and are known to survive for extended periods outside of the animal host. Some members of this group are opportunistic pathogens. The samples will also be tested for the presence of zoonotic pathogens, including Shiga toxigenic E. coli O157:H7 and Salmonella. Pooled soil and vegetable wash samples will be enumerated for the pathogens. Additionally, all samples will be screened for the presence or absence of the target pathogen, using exceptionally sensitive methods specifically designed for the detection of these pathogens from manure and agricultural soils. Dr. Durso has experience using these methods in both research studies and human outbreak investigations. For STEC O157, a six-hour enrichment will be followed by immuno-magnetic separation using magnetic beads specific for the O157 antigen, and plating on differential media. Salmonella will go through a double enrichment in tetrathionate broth followed by Rappaport\'s medium, and then struck out on differential media. All isolates will be confirmed using immunological, biochemical and/or molecular tests, and screened for virulence and antibiotic resistance genes.Objective 3:Approach. We will conduct a partial budget analysis of each factorial treatment combination to determine the potential profitability of the proposed biomulch system. The partial budgets will be calculated as the difference of returns less costs for each crop and growing season. Returns will be estimated from empirical yield data collected in objective 1 activities described above, and a range of crop price estimates from the USDA Economic Research Service. Expenses considered in the analysis will include the cost of biomulch products, partial cost of ownership for a mulch layer, tractor use and fuel, and hourly wages for labor. Sensitivity analysis will consider multiple scenarios for future food, fuel, and labor prices.As part of this analysis, we will compare the profitability of three biomulch end-of-life management strategies including: 1) soil incorporation of biomulch via tillage at the end of the growing season; 2) mechanical removal of biomulch from the field after crop harvest; or 3) concurrent removal of biomulch and crops from the field as a harvest strategy, whereby the entire crop is removed from the soil during the process of biomulch removal and transferred from the field to a post-harvest processing facility.Objective 4:We will developa one credit hour course to be developed in project year one and delivered in years two and three. Curriculum for the course will be developed using case studies of recent weed management innovations for organic specialty crop systems.Objective 5:Project outreach will be carried out through a combination of grower and academic meetings, peer-reviewed publications, and online tools. The majority of outreach efforts will occur in project years two and three. Progress 09/01/20 to 08/31/24 Outputs Target Audience:The target audience for this project included organic farmers, researchers, educators, and students. Organic farmers and vegetable growers were engaged through: 1 poster presentation at the Great Plains Grower\'s Conference in Missouri (200 participants) 1 translated webinar for refugee farmers at Community Crops in Nebraska (8 participants) 2 workshop presentations at the Nebraska Local Food and Healthy Farms Conference (60 participants) 1 field day tour at the University of Nebraska Research Farm (65 participants) Organic researchers, educators, and students were engaged through: 2 invited research seminars - one at Purdue University in Indiana (30 participants) and one at Korea University in South Korea (20 participants) 3 oral presentations and 1 poster presentation at the American Society for Horticultural Sciences annual conferences (85 participants) 1 webinar for Nebraska Natural Resources Conservation Service educators (100 participants) 1 interview with Mulch Matters podcast 1 newsletter article for sustainable mulch educators and researchers 2 peer-reviewed research publications Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?One Ph.D. graduate student (Caleb Wehrbein) continued training and objectives 1-4 will form the basis of his dissertation. A total of 8undergraduate students have been trained in field research methods because of this project and were mentored by the Ph.D. student. How have the results been disseminated to communities of interest?Initial research results were shared with Yazidi refugee farmers from Northern Iraq in beginning farmer programs at the local non-profit organization Community Crops. We developed a 90-minute recorded presentation about organic weed management options in small-scale vegetable production, which was translated into Arabic for the farmers. We workedwith these farmers to test different mulch options on their farms in their pepper and eggplant crops, including biobased organic mulches compared to landscape fabrics and hand weeding. Results were also shared in July 2023 with gardeners at Frogtown Farm in Minneapolis, MN and farmers in the Kilimo Minnesota Organic Incubator Farm. Eight individual gardeners and farmers learned about the biobased fabric mulch production system and tested acommercially available biobased mulch product in organic arugula, carrots, jute, radish, turnip, sweet corn, and cantaloupe. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Objective 1. Year 1 carrots and spinach. Carrot was direct seeded onto PLA mulches and top-dressed with a layer of compost to facilitate carrot germination and rooting through the semi-permeable mulch surface. PLA mulch reduced total weed emergence by 90% relative to bare soil. Yields were not significantly different among mulch types and bare soil controls, in part because weeds were removed weekly after counting. PLA mulch reduced plant available soil nitrate (NO_3) by 47% relative to bare soil controls. After a failed spinach crop in year 1, we replaced spinach in our trials with spring mix lettuce. Years 2 and 3 carrots. Six mulch variants with different levels of thickness and fertilizer weight/types were tested in combination with mixed or yard waste compost in addition to three no mulch treatments. Carrot was seeded on top of PLA mulches without planting holes and top-dressed with 0.5-in of compost to aid germination and establishment through the mulch. All PLA mulches reduced broadleaf and grass weed emergence by \>89% compared to bare ground, and fertilizer-enriched PLA mulches were not different from PLA-only mulches. There was no difference in plant available soil N among mulch types and no mulch controls, which suggests PLA did not immobilize N but also that the fertilizer-enriched mulch did not increase plant available N. PLA-only mulches reduced carrot yield by 26% compared to no mulch compost groups in 2022. Although PLA-only had improved carrot yield by 30% relative to no mulch compost groups and fertilizer-enriched PLA mulches in 2023, yield reductions in fertilizer enriched-PLA was more related to ammonium phytotoxicity in the mixed compost reducing carrot germination. Years 2 and 3 lettuce. Six PLA mulch composites composed of different organic fertilizer types and densities and two compost sources were evaluated against three no mulch treatments. Baby leaf lettuce was planted onto PLA mulch surfaces (or planted into no mulch treatments using seed furrows) in late summer of 2022 and 2023. Compost top-dressings were applied to a 0.5-in thickness in 2022 and to a 0.25-in thickness in 2023. Broadleaf and grass weed emergence was 97% and 89% respectively in PLA mulches relative to no mulch no compost. Soil nitrate was reduced in all treatments at 14-28 days after planting (DAP) compared to 0-14 DAP without differences among fertilizer-enriched PLA mulches, non-enriched PLA mulches, and no mulch groups. Lettuce stand densities were highly variable across treatments in both years as a consequence of supra optimal temperatures for lettuce germination as well as elevated soluble salt concentrations in compost substrates. Positive correlation between stand densities and yields in 2022 indicate that higher yields are achieved with higher establishment. Our data support that lettuce can root through and establish in a PLA mulch when planted in a compost substrate, and the yield of lettuce established in PLA mulch is similar to no mulch control groups given that germination is not inhibited. Objective 2. Microbial quality was assessed before planting and at harvest, with a focus on food safety indicators. All samples (mulch, compost, soil pre-plant and at harvest, vegetables at harvest) were tested for Shiga toxigenic Escherichia coli O157:H7 (STEC O157) and Salmonella. In 2021 STEC was enumerated, and enrichments were performed for detection of targets present at low numbers. In 2022 and 2023, only the enrichment cultures were run. Similarly, there was a methods modification for Salmonella. In 2021 culture-based methods were used to detect and isolate Salmonella, while in 2022 and 2023 a hybrid culture + gene-based PCR method was used. Three fecal indicators were enumerated for all samples. Generic E. coli and Total Coliforms were assayed for all three years, and Enterococcus was assayed for 2021 and 2022. In 2023, the Enterococcus assay was dropped to allow deeper sampling of other parameters. A suite of antibiotic resistance genes was assayed for all samples using PCR and quantitative PCR, and in 2021 selected samples were examined for the presence of nine genes associated with nitrogen cycling. Results included: All samples in all years were negative for STEC O157. Salmonella was only detected in two samples across the three years of the study. Both occurred in 2022, one in a soil before planting, and one on a carrot at harvest. Generic E. coli was occasionally detected, most often in soils and compost, particularly in the compost feedstock that included animal manures. Total coliforms and enterococcus were common in most, sometimes all, soils and compost, and some vegetables. Low numbers were detected on the mulch in 2021, but not in 2022 or 2023. Possibly due to external contamination during initial handling. The occurrence of antibiotic resistance genes was higher in the compost compared to the soil, and absent completely from the mulch samples. There was a slight trend for ARGs to be more frequently detected in samples associated with the manure-based compost. Objective 3. Time spent hand weeding was recorded in each plot, and combined with yield data, was used to determine the hand-weeding-replacement cost for a biobased weed barrier for high density, narrowly spaced crops. Hand weeding plots in this study required an average of 4 minutes/linear bed ft (1/15 hr) A \$15/hr wage x 1/15 hr = \$1/linear bed ft Total cost to implement biobased mulch system = \$0.42/linear bed tt Based on material costs of the most cost-efficient biobased mulches used in this study, the approximate wholesale cost for the mulch = \$0.35/linear bed ft Compost topdressing used = \$0.06/linear bed ft Custom application of compost and mulch = \$0.01/linear bed ft In this study, the biobased mulch system was 42% of the total cost of hand weeding and mulch will remain more cost effective than hand weeding if growers are paying for hand weeding for more than 1.7 minutes per linear bed ft. Objective 4. We developed and delivered a 1-credit independent study titled \"Organic Weed Management for Small Farms and Gardens\" to 7 graduate students at the University of Nebraska - Lincoln in spring semesters of 2023 and 2024. Students in the course explore and synthesize current scientific literature on ecological weed management, organic weed management philosophies, stale seed bedding, tarping, biobased herbicides, mulches, cover crops, tillage, flaming, and robotics, and then create an organic weed management plan for a farm. Objective 5. Disseminate project results to current and future organic farmers and researchers. Project results were disseminated to current and future organic farmers, researchers and educators through a variety of methods most appropriate for each group. Organic farmers and vegetable growers were engaged through: 1 poster presentation at the Great Plains Grower\'s Conference in Missouri (200 participants) 1 translated webinar for refugee farmers at Community Crops in Nebraska (8 participants) 2 workshop presentations at the Nebraska Local Food and Healthy Farms Conference (60 participants) 1 field day tour at the University of Nebraska Research Farm (65 participants) Organic researchers, educators, and students were engaged through: 2 invited research seminars - one at Purdue University in Indiana (30 participants) and one at Korea University in South Korea (20 participants) 3 oral presentations and 1 poster presentation at the American Society for Horticultural Sciences annual conferences (85 participants) 1 webinar for Nebraska Natural Resources Conservation Service educators (100 participants) 1 interview with Mulch Matters podcast 1 newsletter article for sustainable mulch educators and researchers 2 peer-reviewed research publications Publications Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Wehrbein, C., I. Kadoma, and S.E. Wortman. 2024. First field evaluation of a polylactic acid-based weed barrier with compost for carrot production. HortTechnology 34(2):204-210. https://doi.org/10.21273/HORTTECH05370-23 Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Shcherbatyuk, N., S.E. Wortman, D. McFadden, S. Weyers, W. Ahmad, D. Bajwa, S.P. Galinato, A. Formiga, G. Gramig, and L.W. DeVetter. 2024. Alternative and emerging mulch technologies for organic and sustainable agriculture in the United States: A review. HortScience 59(10):1524-1533. Progress 09/01/22 to 08/31/23 Outputs Target Audience:Project results from 2021 and 2022 were shared with organic farmers, researchers, and educators through a presentation at the Local Food and Healthy Farms Conference in Aurora, NE (40 growers and 4 educators), a poster at the American Society for Horticultural Science annual conference (20 participants and archived online), and an invited seminar at Purdue University Department of Horticulture and Landscape Architecture (30 researchers and educators). Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?One Ph.D. graduate student (Caleb Wehrbein) continued training and objectives 1-4 will form the basis of his dissertation. A total of 6 undergraduate students have been trained in field research methods because of this project and were mentored by the Ph.D. student. How have the results been disseminated to communities of interest?Results were shared in July 2023 with gardeners at Frogtown Farm in Minneapolis, MN and farmers in the Kilimo Minnesota Organic Incubator Farm. Eight individual gardeners and farmers learned about the biobased fabric mulch production system and tested the first commercial product in organic arugula, carrots, jute, radish, turnip, sweet corn, and cantaloupe. What do you plan to do during the next reporting period to accomplish the goals?Objective 1. We will analyze data from the 2023 field trials and begin preparation of publications in peer-reviewed journals. Objective 2. We will finalize lab work to detect and quantify potential foodborne pathogens from 2023 soil, compost, and biomulch samples. Objective 3. We will complete analysis of partial budgets using empirical data from field trials along with cost estimates from biomulch manufacturers. Objective 4. The new course, \"Organic Weed Management for Small Farms and Gardens\" will be offered for the second time and we will finish development of the course for non-academic credit to stakeholders at Community Crops and beyond. Objective 5. Project results from 2023 will be presented to organic farmers at the Local Food Healthy Farms Conference in Columbus, NE and to organic researchers and educators at the American Society for Horticultural Science annual conference in Hawaii. We will prepare publication of project results in peer-reviewed journals. Impacts What was accomplished under these goals? This project is framed by three research objectives, one education objective, and one extension objective: Objective 1.Quantify the effects of biomulch properties and compost top-dressings on agronomic performance in organic spinach and carrot production systems, including weed suppression, nitrogen dynamics, soil temperature and moisture, disease incidence, and crop yield. Objective 2.Determine the effect of biomulch and compost top-dressings on foodborne pathogens and fecal indicators in organic spinach and carrots. Objective 3.Perform a partial budget analysis to identify potential labor and cost savings of the proposed biomulch system for organic spinach and carrots. Objective 4.Develop curriculum and teach a new online course for academic and professional audiences titled, \"Organic Weed Management Innovations for Specialty Crops.\" Objective 5.Disseminate project results to current and future organic farmers and researchers. Objective 1. Field experiments were conducted in summer 2023 in Lincoln, NE in organic carrot and lettuce crops. Treatments included six different biobased mulch fabrics varying in thickness and nutrient composition \polylactic acid (PLA) @ 120 g/m2, PLA @ 180 g/m2, PLA @ 120 g/m2 + 30 g/m2 turkey litter fertilizer, PLA @ 120 g/m2 + 90 g/m2 turkey litter fertilizer, PLA @ 120 g/m2 + 30 g/m2 soybean meal fertilizer, PLA @ 120 g/m2 + 90 g/m2 soybean meal fertilizer\ and a no mulch control, and two different compost media for seedling establishment (yard waste feedstock and animal manure feedstock). Data was collected for weed density, soil nitrogen availability, soil and surface temperature, soil moisture, and crop establishment and yield. Results for 2023 are being analyzed but results for carrot and lettuce in 2022 have been analyzed and are summarized below. In 2022, PLA mulch treatments (regardless of weight basis or fertilizer treatment) reduced emerging grass/broadleaf weeds by 86% and 92%, respectively, compared to no mulch controls in both crops. Reductions in time spent hand weeding were proportional to weed density. In addition to the weed suppressive benefits of the biofabric mulch, it appears compost alone has some weed suppressive potential. Compost presence reduced density of grass/broadleaf weeds by 66% and 51%, respectively, compared to no mulch, no compost control in lettuce. In contrast to our expectations, fertilizer-enriched biofabric mulch had no effect on soil nitrate availability relative to controls or PLA-only mulch. Carrot yield was not affected by mulch treatments, whereas lettuce yield was reduced 23 to 56% in PLA-120 and PLA-180 treatments compared to controls and fertilizer-enriched mulch. Yield reduction in PLA-only mulch, but not PLA mulches enriched with fertilizer, suggests the fertilizers may have helped counteract potential N immobilization from the carbon-rich mulch (despite a lack of measured differences in potential N update via PRS probes). The lack of yield differences between hand-weeded controls and mulch treatments in carrots and most lettuce treatments suggest the mulches were effective in eliminating weed-induced yield loss. Objective 2. We collected soil, compost, and biofabric samples at planting, and plant samples at harvest in all carrot and lettuce plots. These samples were frozen for PCR analysis of potential foodborne pathogens this winter. Analysis of 2022 results suggest that none of the biofabric mulches or compost are a source of foodborne pathogens nor are they contributing to enrichment of foodborne pathogens in the soil or on the harvested plant material. Objective 3. Data was collected for time spent hand-weeding each plot throughout the growing season along with time spent applying mulch and compost treatments relative to planting operations in the control plots. Manufacturing and retail costs of a commercial biofabric mulch have been collected. Along with crop yields, these labor and supply costs will serve as the major variables in the partial budget analysis. Objective 4. Developed and delivered a 1-credit independent study titled \"Organic Weed Management for Small Farms and Gardens\" to 5 graduate students at the University of Nebraska - Lincoln in spring semester 2023. Objective 5. Project results from 2021 and 2022 were shared with organic farmers, researchers, and educators through a presentation at the Local Food and Healthy Farms Conference in Aurora, NE (40 growers and 4 educators), a poster at the American Society for Horticultural Science annual conference (20 participants and archived online), and an invited seminar at Purdue University Department of Horticulture and Landscape Architecture (30 researchers and educators). Publications **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:We presented results from project year one in a poster at the Great Plains Growers Conference in St. Joseph, MO, titled, \"RootThru Biofabric: Integrated nutrient and weed management for leafy greens, carrots, and strawberries.\" There were over 200 specialty crop growers, researchers, and educators in attendance at the two-day conference, many of whom are certified organic.

Results were also shared with 25 specialty crop researchers and educators through an oral presentation at the American Society for Horticultural Science annual conference in Chicago, IL, titled, \"Developing a biobased mulch system for carrot production: Effects on weed suppression, soil fertility, and yield.\" We also collaborated with Community Crops, a non-profit organization in Lincoln, NE, to provide organic weed management education to eight Yazidi farmers (an ethnic minority group from Northern Iraq). Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?One Ph.D. graduate student (Caleb Wehrbein) continued training and objectives 1-4 will form the basis of his dissertation. Three undergraduate students were trained in field research methods as a result of this project, and were mentored by the Ph.D. student. How have the results been disseminated to communities of interest? Initial research results were shared with Yazidi refugee farmers from Northern Iraq in beginning farmer programs at the local non-profit organization Community Crops. We developed a 90-minute recorded presentation about organic weed managment options in small-scale vegetable production, which was translated into Arabic for the farmers. We are also working with these farmers to test different mulch options on their farms in their pepper and eggplant crops, including biobased organic mulches compared to landscape fabrics and hand weeding. What do you plan to do during the next reporting period to accomplish the goals?Objective 1. We will conduct a third year of field trials in organic carrot and lettuce identical to the treatment structure in year two. Objective 2. We will continue lab work to detect and quantify potential foodborne pathogens in this production system. Objective 3. We will begin analysis of partial budgets using empirical data from field trials along with cost estimates from manufacturers. Objective 4. The course will be offered for the first time as an experimental independent study, and development will continue to offer the class for non-academic credit to stakeholders at Community Crops and beyond. Objective 5. Project results from years one and two will be presented to organic farmers at the Nebraska Specialty Growers Conference in 2023. **Impacts** What was accomplished under these goals? This project is framed by three research objectives, one education objective, and one extension objective: Objective 1.Quantify the effects of biomulch properties and compost top-dressings on agronomic performance in organic spinach and carrot production systems, including weed suppression, nitrogen dynamics, soil temperature and moisture, disease incidence, and crop yield. Objective 2.Determine the effect of biomulch and compost top-dressings on foodborne pathogens and fecal indicators in organic spinach and carrots. Objective 3.Perform a partial budget analysis to identify potential labor and cost savings of the proposed biomulch system for organic spinach and carrots. Objective 4.Develop curriculum and teach a new online course for academic and professional audiences titled, \"Organic Weed Management Innovations for Specialty Crops.\" Objective 5.Disseminate project results to current and future organic farmers and researchers. Objective 1. Field experiments were conducted in summer 2022 in Lincoln, NE in organic carrot and lettuce crops. Treatments included six different biobased mulch fabrics varying in thickness and nutrient composition \polylactic acid (PLA) @ 120 g/m2, PLA @ 180g/m2, PLA @ 120g/m2+ 30g/m2turkey litter fertilizer, PLA @ 120g/m2+ 90g/m2turkey litter fertilizer,PLA @ 120g/m2+ 30g/m2soybean meal fertilizer, PLA @ 120g/m2+ 90g/m2soybean meal fertilizer\ and a no mulch control, and two different compost media for seedling establishment (yard waste feedstock and animal manure feedstock).Data was collected for weed density, soil nitrogen availability, soil and surface temperature, soil moisture, and crop establishment and yield. In contrast to year one results, carrot establishment was limited by water erosion of compost media off of the bed tops in mulched plots, and the effect worsened with increasing thickness of the PLA. Established carrot populations were reduced by 45% in PLA-120 mulch and 58% in PLA-180 mulch compared to the bare soil + compost controls. The PLA-120 mulch was used in year one, and no reductions in stand establishment were measured, but we experienced more intense rainfall events during crop establishment in year two. A new planting method is being developed to remediate this issue in project year three where small furrows will be created lengthwise on bed tops to prevent erosion off the sides of beds and also create a deeper media profile for establishment of roots. Plots with biofabric, regardless of type, increased volumetric surface moisture in the top 15 cm of soil by 48% compared to the bare soil control. Biofabric reduced total weed emergence one month after planting by 86% to 98% depending on mulch type. PLA-120 and PLA-180 were most effective against weeds, and the presence of fertilizers in the fabric seemed to reduce weed suppression slightly. Similarly, biofabrics reduced hand weeding labor requirements and cost by 92% to 98%. Lettuce were planted in July of year two using the same experimental design as for carrot, and harvested two times in August and September. Data will be analyzed and reported during the next reporting period. Objective 2. We collected soil, compost, and biofabric samples at planting, and plant samples at harvest in all carrot and lettuce plots. These samples were frozen for PCR analysis of potential foodborne pathogens this winter. Analysis of year one results suggest that none of the biofabric mulches or compost are a source of foodborne pathogens nor are they contributing to enrichment of foodborne pathogens in the soil or on the harvested plant material. Objective3. Data was collected for time spent hand-weeding each plot throughout the growing season, and manufacturers were contacted to determine a range of possible biofabric production, wholesale, and retail costs. Along with crop yields, these labor and supply costs will serve as the major variables in the partial budget analysis Objective 4. Developed 1-credit independent study titled \"Weed Management in Organic Specialty Crops\" that will be offered in January 2023. Course structure, activities, and bibliography of course readings were developed. Objective 5.

Project results from year one were shared to organic famers, researchers, and educators through a poster at the Great Plains Growers Conference (200 attendees) and an oral presentation at the American Society for Horticultural Science annual conference (25 attendees). **Publications** - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Wehrbein, C., and S.E. Wortman. 2022. Developing a biobased mulch system for carrot production: Effects on weed suppression, soil fertility, and yield. American Society for Horticultural Science (ASHS) Annual Conference. Chicago, IL. - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Wortman, S.E., C. Wehrbein, and I. Kadoma. 2022. RootThru Biofabric: Integrated nutrient and weed management for leafy greens, carrots, and strawberries. Great Plains Growers Conference, St. Joseph, MO. **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience: Nothing Reported Changes/Problems:We have replaced spinach in our trials with spring mix lettuce. Spinach is a difficult crop to grow in Nebraska due to the potential for extreme heat during seedling emergence. The organic market demand for spring mix lettuce and the weed management challenges are similar; thus, we believe this is a suitable alternative with comparable potential for impact in the organic farming community. What opportunities for training and professional development has the project provided?One Ph.D. graduate student (Caleb Wehrbein) began training and objectives 1-4 will form the basis of his dissertation. Three undergraduate students were trained in field research methods as a result of this project, and were mentored by the Ph.D. student. How have the results been disseminated to communities of interest?Initial research results were shared with Yazidi refugee farmers in beginning farmer programs at the local non-profit organization Community Crops. We developed a 1.5 hour recorded presentation about organic weed managment options in small-scale vegetable production, which was translated into Arabic for the farmers. We then participated in a field day to answer farmer questions about organic weed management and helped them design and manage on-farm trials to test new methods. What do you plan to do during the next reporting period to accomplish the goals?Objective 1. We will conduct a second year of field trials, which will include four new biofabric treatments: 1) 180 g/m2 PLA + Sustane organic fertilizer, 2) 240 g/m2 PLA + Sustane organic fertilizer, 3) 180 g/m2 PLA + soybean meal organic fertilizer, and 4) 240 g/m2 PLA + soybean meal organic fertilizer. We will grow carrots and spring mix lettuce in these biofabric by compost top dressing treatments and collect the same agronomic data as in year one. Objective 2. We will begin lab work to detect and quantify potential foodborne pathogens in this production system, and use this information to inform sampling efforts and experimental design in year two. Objective 3. The partial budget analysis will be conducted in year three using empirical data from the field trials. Objective 4. Course development will begin in year two. Objective 5. Project results from year one will be presented to organic farmers at the inaugural Nebraska Specialty Crop Growers Conference in 2022. **Impacts** What was accomplished under these goals? This project is framed by three research objectives, one education objective, and one extension objective: Objective 1.Quantify the effects of biomulch properties and compost top-dressings on agronomic performance in organic spinach and carrot production systems, including weed suppression, nitrogen dynamics, soil temperature and moisture, disease incidence, and crop yield. Objective 2.Determine the effect of biomulch and compost top-dressings on foodborne pathogens and fecal indicators in organic spinach and carrots. Objective 3.Perform a partial budget analysis to identify potential labor and cost savings of the proposed biomulch system for organic spinach and carrots. Objective 4.Develop curriculum and teach a new online course for academic and professional audiences titled, \"Organic Weed Management Innovations for Specialty Crops.\" Objective 5.Disseminate project results to current and future organic farmers and researchers. Objective 1. Field experiments were conducted in summer 2021 in Lincoln, NEin organic spinach, carrot, and leafy greens. Treatments included two polylactic acid (PLA)biofabric mulch thicknesses (80 and 120 g/m2), two compost sources, and bare soil controls with and without compost. Data was collected for weed density, soil nitrogen availability, soil and surface temperature, soil moisture, and crop yield. Surface temperatures of compost topdressings on biofabrics were up to 1°C warmer than bare soil, but below-surface (2.5 cm) temperatures were similar across treatments.Compared to the bare soil controls (with and without compost),season-long weed emergence was reduced by 93% in the thicker biofabric(120g/m2) and 88% in the thinner biofabric (80 g/m2). Given the reduced weed suppression in the thinner biofabric, it will be omitted from year two field trials. Despite the presence of a compost topdressing, the PLA mulch and its high C:N did reduce soil mineral nitrogen availability by 33-59%for the first 6 weeks of the growing season. To address this issue, we will include four new biofabric treatments in 2022 trials that include organic fertilizers embedded in the matrix of PLA fibers (these treatments were excluded in 2021 trials due to supply chain issues at 3M, the manufacturer of these prototype biofabrics). Compared to the no biofabric and no compost control, carrot yield was increased by an average of 23% across all compost and biofabric treatments. Because weeds were removed shortly after emergence, the weed suppressive value of the biofabrics is not reflected in this yield estimate; however, it is noteworthy that yield in biofabric treatments was not reduced compared to compost treatments given the observed differences in available soil N. Spinach yield data was not collected due to poor establishment across all treatments. A preliminary trial was conducted in these plots to determine a replacement crop for 2022; spring mix lettuce grew well in all compost by biofabric treatments and will replace spinach in 2022. Objective 2. We collected soil, compost, and biofabric samples at planting, and plant samples at harvest in select spinach and carrot plots.

These samples were frozen for analysis of potential foodborne pathogens this winter. Objectives 3-5. No upates to report. **Publications**

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Strategies in Support of Organic Dairy Production and its Livelihood

Accession No.	1023723
Project No.	NYCV478-908
Agency	NIFA NYCV\
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Project Status	NEW
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Grant Amount	$417,277
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Investigator(s)	Mohammed, H.

NON-TECHNICAL SUMMARY

We are planning to carryout molecular, bacteriological and epidemiologic studies on water- and foodborne pathogens in organic and traditional dairy operations in New York State to identify factors that led to their introduction and the evolution of antimicrobial resistant foodborne pathogens among them. The focus will be on Campylobacter, Escherichia coli, and Salmonella spp. and cryptosporidium species. We will identify the factors that play role in the introduction transmission of these pathogens among these operations. We will develop recommendation to mitigate their associated risk and promote organic farming. The recommendations will be shared with the producers, their associated organizations and with the extension personnel in hope of supporting the livelihood of these operations.

OBJECTIVES

1. Determine the dynamic of zoonotic food- and waterborne pathogens Escherichia coli, Salmonella spp., Listeria monocytogenes, and Cryptosporidium spp. among agricultural ecosystems in New York State (NYS). 2. Identify sources, ecological factors and management practices associated with the likelihood of introduction, and survival of these pathogens through epidemiologic studies. 3. Develop risk assessment models using both deterministic and stochastic approaches to delineate the pathways by which these pathogens could enter the food chain and identify critical control points to mitigate their associated risk. 4. Integrate findings into extension and educational programs for the purpose of closing the knowledge gap in mitigating the risks associated with these pathogens. ?

APPROACH

We are planning to carry out a prospective cohort study. A combination of epidemiologic and molecular comparative studies will be carried out. The target population: organic and conventional operations. A random sample from each subtype will be selected and enrolled in the study. Milk filters and composite fecal samples will be collected and screened for the presence of the targeted pathogens. If any of the operations tested positive for any of the pathogens the farm will be enrolled in a nested case-control with an-in-depth investigation. Animal, environmental, and product samples be collected and examined for the presence of these pathogens using a combination of bacterial, parasitic, and molecular approaches. Knowledge gained will be integrated in risk assessment models the results of which will be integrated into educational programs to be shared with the stakeholders. Progress 09/01/23 to 08/31/24 Outputs Target Audience:We have been collecting samples from organic and traditional dairy operations in New York State in collaboration with the veterinary staff at the milk quality program at Cornell. The samples consist of in-line milk filters, milk, and fecal samples. The samples are collected by the Extension staff to ensure anonymity, and the results of the analyses were sent to extension personnel to feedback to the producers. All of the producers have been notified of the results of the presence of the targeted pathogens in the respective samples. All the producer are offered the option of carrying out further investigation of the source(s) of the pathogens in their operations. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?I have offered opportunities for individuals to learn about approaches to investigating foodborne pathogens in dairy operations. And ways to collect data and collate data for the purpose of analyses. How have the results been disseminated to communities of interest?For now, all the results of the bacteriological and parasitological analyses are reported back to the Veterinary extension veterinarian to report back to the farmers. What do you plan to do during the next reporting period to accomplish the goals?We are planning to continue collecting samples, analyzing the samples for the presence of the targeted pathogens, developing the risk assessment model, and producing reports to be integrated into the extension and education program. Impacts What was accomplished under these goals? As of December 17th, 2024, Mohammed Lab has received milk, milk filter, and fecal samples from 100 different organic and traditional farms. For the Dairy Pathogens Project, 295 composite samples were processed and tested for six pathogens: E.coli, Salmonella, Listeria Monocytogenes, Campylobacter2, S. Aureus1, and K.pneumoniae3. Additionally, samples from individual cows, milking systems, bulk water, and dry bedding were examined by request of 4 farms seeking to specifically trace Campylobacter presence in their samples. Organic Farms Data was collected from a total of 27 Organic Farms, each providing a milk sample, a milk filter, and a fecal sample. The prevalence of pathogens observed from the composite samples was as follows: 80% tested positive for Staphylococcus aureus1, 48% tested positive for Escherichia coli, 19% tested positive for Salmonella, 15% tested positive for Listeria monocytogenes, and there were no cases positive for either Campylobacter2 or K.pneumoniae3. 70% of milk filters tested positive for a pathogen compared to the 30% of milk samples that had tested positive. Fecal samples received were sent to the Animal Health Diagnostics Center for detecting presence of Giardia and Cryptosporidium, from which only 4% were found positive for Cryptosporidium. E. coli was found among 48%, Salmonella spp. Among 19%, L. monocytogenes among 15% of the samples, Staphylococcus aureus 80% Traditional Farms Samples were also collected from a total of 68 Traditional Farms. The samples consisted of bulk milk samples, a milk filter, and composite fecal sample. The prevalence of pathogens observed from the composite samples was as follows: 62% tested positive for E. coli, 48% tested positive for S. aureus, 37% tested positive for Salmonella spp., 12% tested positive for L. monocytogenes, and 3% tested positive for Campylobacter spp. None of the samples tested positive for K. pneumonia. 66% of milk filter samples tested positive for at least one pathogen compared to the 34% of milk samples that had tested positive. Among the fecal samples, none were positive for Giardia spp. However, 15% tested positive for Cryptosporidium spp. Individual Sample Testing Farm 76, we were requested to test milk samples from a total of 48 individual cows for Campylobacter spp. Alongside the routine testing of composite milk, milk filer, and fecal samples, the individual milk samples all came out negative for Campylobacter. We received 40 milk samples from individual cows from farm \# 80 to be tested for Campylobacter. In addition, 4 milking systems and one sample of bulk tank. The milk and milk filter tested positive for Campylobacter, and of the individual cows, only one tested positive. From routine testing, the composite milk and milk filter tested positive for Salmonella, and the remaining individual milk samples were then tested for Salmonella. From the testing, 4 samples were positive for the presence of Salmonella spp. Farm 95, were requested to test milk samples for Campylobacter from 39 individual cow. Additionally, we were requested to test the bulk tank milk, water, rinse cycle dump water, milk filter, and dry cow bedding for possible presence as it was suspected to be the source for Campylobacter presence. Both the bulk milk and milk filter tested negative, as well as the bulk water troughs, rinse cycle dump, and dry cow bedding. From all the 39 individual milk samples received, only one cow tested positive. After the first batch of samples were tested (5/15/24), a second batch were sent (7/16/24) to additionally confirm there was no longer any presence of Campylobacter in the farm samples. All of the bulk milk and 33 individual cow milk samples received tested negative. Farm 103, we were requested to test milk samples from a total of 59 individual cows for Campylobacter. Alongside the routine testing of composite milk, milk filer, and fecal samples, the individual milk samples all came out negative for Campylobacter. After the first batch of samples were sent (8/12/24) and tested for the pathogen, a second batch was sent (9/5/24) to confirm the results of the first batch. From the bulk milk sample received for confirmation, the sample again tested negative. Footnotes: 1-Starting onwards from Farm 60, the lab began testing for S. aureus. 2-Starting onwards from Farm 57, the lab began testing for Campylobacter. 3-Starting onwards from Farm 91, the lab began testing for K. pneumoniae Publications Progress 09/01/22 to 08/31/23 Outputs Target Audience:We have been collecting samples from organic and traditional dairy operations in New York State in collaboration with the veterinary staff at the milk quality program at Cornell. The samples consist of in-line milk filters, milk, and fecal samples. The samples are collected by the Extension staff to ensure anonymity, and the results of the analyses were sent to extension personnel to feedback to the producers.

All of the producers have been notified of the results of the presence of the targeted pathogens in the respective samples. All the producer are offered the option of carrying out further investigation of the source(s) of the pathogens in their operations. Changes/Problems:Because of the COVID situation, there have been additional delays in recruiting farms/operations in the study. What opportunities for training and professional development has the project provided?I have offered opportunities for individualsto learn about approaches to investigating foodborne pathogens in dairy operations. And ways to collect data and collate data for the purpose of analyses. How have the results been disseminated to communities of interest?For now, all the results of the bacteriological and parasitological analyses are reported back to the Veterinary extension veterinarian to report back to the farmers. What do you plan to do during the next reporting period to accomplish the goals?We are planning to continue collecting samples, analyzing the samples for the presence of the targeted pathogens, developing the risk assessment model, and producing reports to be integrated into the extension and education program. Impacts What was accomplished under these goals? The Mohammed Lab has received samples from 81 different farms. For the Dairy Pathogens Project, 241 composite samples were processed and tested for five pathogens: E.coli, Salmonella, Listeria Monocytogenes, Campylobacter, and S. Aureus. Additionally, 93 individual samples from cows, milking systems, and bulk water were examined by request of certain farms seeking to trace pathogens within their samples. Organic Farms Data was collected from a total of 24 Organic Farms, each providing a milk sample, a milk filter, and a fecal sample. The prevalence of pathogens observed from the composite samples was as follows: 83% tested positive for Staphylococcus aureus1, 33% tested positive for Escherichia coli, 21% tested positive for Salmonella, 17% tested positive for Listeria monocytogenes, and there were no cases positive for Campylobacter. 67% of milk filters tested positive for a pathogen compared to the 33% of milk samples that had tested positive. Traditional Farms Data was collected from a total of 57 Traditional Farms, with most of the farms providing a milk sample, a milk filter, and a fecal sample2. The prevalence of pathogens observed from the composite samples was as follows: 67% tested positive for Escherichia coli, 50% tested positive for Staphylococcus aureus1, 28% tested positive for Salmonella, 14% tested positive for Listeria monocytogenes, and there 4% tested positive for Campylobacter. 72% of milk filters tested positive for a pathogen compared to the 28% of milk samples that had tested positive. Individual Sample Testing For Farm 76, we were requested to test milk samples from a total of 48 individual cows for Campylobacter. Alongside the routine testing of composite milk, milk filer, and fecal samples, the individual milk samples all came out negative for Campylobacter. For Farm 80, we were requested to test for Campylobacter but for milk samples from 40 individual cows, 4 milking systems, and one sample of bulk tank water. Both the milk and milk filter tested positive for Campylobacter, and of the individual cows, only one tested positive. From routine testing, the composite milk and milk filter tested positive for Salmonella, and the remaining individual milk samples were then tested for Salmonella. From the testing, 4 samples were positive for the presence of Salmonella. Publications **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:We have been collecting samples from organic and traditional dairy operations in New York Statein collaboration with the veterinary staff at the milk quality program at Cornell. The samples consist of in-line milk filter, milk, and fecal samples. The samples are been collected by the Extension staff to ensure anonymity and the results of the analyses were send extension personnel to feed back to the producers. All the of the producers have been notified of the results of the presence of the targeted pathogens in the respective samples. All the producer are been offered the options of in carrying out further investigation of the source(s) of the pathogens on their operations. To Date 47 operations are been sampled. There has been a delay in the samples\` collection because of the COVID situation. Changes/Problems:Because of the COVID situation there have been additional delay in recruiting farms/operations in the study. We have expanded our team and added Dr. Michael J. Zurakowski, a Research Extention Specialist, in our Depart to the research team. He will help in the collection of the samples from the different operation in the field. What opportunities for training and professional development has the project provided?1. We have enrolled a post-doctorlal associate/Research associate in the project. 2. We also enrolled two undergraduate students to train in epidemiologic and bacteriological research methods. How have the results been disseminated to communities of interest?For the time being, all the results of the bacteriological and parasitological analyses are reported back to the Veterinary extension veterinarian to report back to the farmers. What do you plan to do during the next reporting period to accomplish the goals?We are planning to continue collectingsamples, analysing the samples for presence of the targeted pathogens,develop the risk assessment model, and produce reports to be integrated in extension and education program. **Impacts** What was accomplished under these goals? 1. We have continued to recruit farms, collecting animals and enviromental samples, analyze these samples for the presensense of the three bacterial food and waterborne pathogens. In addition, the samples are being analyzed for the presense of the protozoan, Cryptosporidium spp. At the same time we are continuing to collect data on the putative risk factors associated with these pathogens. The data are being collected and validated for preperation for analysis. 2. Data on the risk factors are being collected and entered in a database program for analyses.. We are reserving the analyses until the data are complete on60 farms. The purpose is to avoid any premature conclusions. 3. We are waiting until the data arecompleted on all the farm to perform the statisitcal analyses and develop a risk assessment model. 4.

The extention and education program is on-hold until the data are analyzed. **Publications** **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience:We have been collecting samples from traditional/conventional and organic milk producers in New York State. We have been collecting these samples in collaboration with the veterinary staff at the milk quality program at Cornell.The samples consist of in-line milk filter, milk, and fecal samples. The samples are been collected by the Extension staff to ensure anonymity and the results of the analyses were send extension personnel to feed back to the producers. All the of the producers have been notified of the results of the presence of the targeted pathogens in the respective samples. All the producer are been offered the options of in carrying out further investigation of the source(s) of the pathogens on their operations. To Date 15 operations are been sampled. There has been a delay in the samples\` collection because of the COVID situation. Changes/Problems: We have expanded our team and added Dr. Michael J. Zurakowski, a Research Extention Specialist, in our Depart to the research team. He will help in the collection of thesamples from the different operation in the field. What opportunities for training and professional development has the project provided?We have recruited a veterinarin with a Masters degree (MSc). She is also interested in a PhD training and her application is in progress. How have the results been disseminated to communities of interest?Yes, all of the producers who are enrolled in the study todate have received the results of the samples that are been collected from their operations. What do you plan to do during the next reporting period to accomplish the goals?We are planning to continue to collecting samples and data on the factors that are associated with these operations from the target population. The data will be analyzed to identify the sources of these pathogens and recommend strategies to minimize and mitigate their associated risk. **Impacts** What was accomplished under these goals? We have just started our research activities since Oct 2020 and have sampled 15 operations. The targeted samples were tested for the presence of the pathogens of interest and the results are been conveyed back to the producer. **Publications**

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Rapid Return on Investment: Defining Rates of Soil Health Improvement During Organic Transition in the Southeast

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Investigator(s)	Woodley, A. L.

NON-TECHNICAL SUMMARY

The soils we have chosen in this study represent 1.2 million ha of class prime farmland spanning the entire Coastal Plain region of the southeast. The agricultural landscape found on these soils is diverse, however there is a unifying feature that all farmers are challenged with in this region, low soil C and low soil health. Transition to organic management is challenging due to short-term limitations in soil health and productivity before longer-term agroecosystem benefits can be realized. This challenge is exacerbated by the sandy soils and warm climate of the southeastern Coastal Plain. When managed conventionally, these soils have very low (\<1%) concentrations of organic matter. Yet, preliminary data from the soil survey show that reforested sites have significantly increased SOC (45-200%), therefore there is clearly potential for these soils to retain more C. By most soil health metrics, which are strongly correlated to soil organic carbon (SOC) content, these soils are considered unhealthy and may remain in a poor state of soil health for a substantial period after transition. Determining the potential of southeastern Coastal Plain soils to accrue C, defining possible rates of sequestration, and identifying practices that can accelerate short-term gains can help guide the transition to organic management. Therefore, the goal of this integrated research, extension and education initiative is to develop an understanding of soil carbon and soil health accrual over time in organically managed fields in the characteristically low-C soils of the coastal plain region of the Southeast. Our two-pronged approach will use on-farm sampling and controlled field experiments to understand soil C and soil health dynamics from the onset of transition to organic into the long-term (15+ years). Field and on-farm experiments will address the following four objectives: 1) determine a baseline soil carbon accrual rate in the region by comparing paired conventional agriculture and afforested sites; 2) assess soil carbon and soil health indicators on 20 organically managed fields along a chronosequence from 1 to 20+ yrs from transition to organic; 3) establish a field experiment at two sites, evaluating different carbon input strategies to jump start soil C accrual and soil health metrics for comparison to the baseline and sampled chronosequence of organic farms; and 4) educate researchers, farmers, students and extension agents through an integrated outreach program, highlighting long-term outcomes and short-term strategies for accelerated soil health improvement during transition. Our results will provide key insights on soil C stocks in organic farms within this region and help determine which C input strategies could improve soil health rapidly during the challenging transition period to organic.?

OBJECTIVES

The major goal of this research project is to create a framework and protocol to understand the lower and upper boundaries of soil health and soil carbon sequestration potentials based on transition from organic farming. Traditionally this would require long-term field experiments, however the approach in this study avoids the need for long-term experimentation by sampling organic farms that have been in organic management over a range of years to create a Chrono sequence. In this study we have constrained this analysis on the coastal plain region of North Carolina, a region characterized by low soil carbon and poor soil health. The carbon and soil health accrual rate determination developed will be used to compliment the research station field experiments. The second goal of this study is to determine how rapidly soil health and carbon can be improved through intensive management during the 3-yr transition period from conventional to organic through the use of organic amendments and cover crops in a representative crop rotation found in this region. Specific objectives are as follows:1) Establish baselines of mean soil C stocks for conventional agricultural fields and mature secondary growth forest stands on the Atlantic Coastal Plain.2) Evaluate the long-term effects of organic agriculture (\>15 years) on soil C and related soil health metrics using Chronosequence methods.3) Evaluate carbon (composts, bio char, cover crop biomass) input strategies during a 3-year transition period in a high disturbance crop rotation on soil organic carbon, soil health indicators and crop yields.

APPROACH

Chronosequence On-Farm Study We will utilize paired site methods to evaluate a minimum of 10 plots representing SOC pools under conventional agriculture and maximum expected SOC pools under mature (\>50 years) forest. The 10 paired plots will be used to derive a mean/median baseline between initial and projected maximum SOC for the Goldsboro/Norfolk soil series. We will utilize fixed incremental sampling at 0-5, 5-10, 10-20, 20-30, 30-50, 50-75, and 75-100 cm for statistical comparisons by depth among study sites. Soil measurements will include bulk density, particle size distribution, and total C/N concentration. Soil C concentrations will be converted to landscape pools and compared between conventional farm fields and mature secondary growth forest. These data will be used as the minimum-maximum boundaries between which organic systems can be compared to detect short and long-term changes in soil C accrual.We will select a minimum of 15 and maximum of 20 organic farm fields mapped as Goldsboro or Norfolk series to be sampled by stratified age groups. We will define age since transition groups as recent since transition (1-5 years in organic agriculture), mid since transition (5-10 years in organic agriculture), and late since transition (10+ years in organic agriculture). In the first field season we will replicate soil measurements in a single soil map unit at representative sites from each of the three defined age groups to understand within-site variability in soil properties. The data will be used to construct a regional chronosequence for SOC and associated soil health metrics. Effort: This chronosequence will be used both to identify the trajectory of organic management system soil health over time after transition and as a metric to evaluate C input strategies during transition as described the research station project. Soil metrics will include core method bulk density and soil texture via hydrometer. Saturated hydraulic conductivity and water holding capacity will be obtained from cores. Aggregate stability as mean weight diameter will be assessed via wet sieving. Soil pH will be measured using 1:1 soil:DI water and 1:2 soil:CaCl2, and soil electrical conductivity will be measured using 1:2 soil:DI water. Cation exchange capacity (CEC) and base saturation will be quantified for the upper sandy horizons and at the transition to the clayey subsoil using NH4 OAc, pH 7 extractions. Total soil C and N concentrations will be quantified via thermal combustion. Carbon and N mineralization potential will be measured via incubation, and labile C will be quantified as permanganate-oxidizable C. Enzymes: â-glucosidase, â-glucosaminidase, phosphatase and arylsulfatase will be assayed as indicators for nutrient cycling. Lastly, soil protein will be measured as an indicator of bioavailable N. Effort: Regression techniques will be utilized to create soil pedotransfer functions between SOC and other soil health indicators to quantitatively establish the connections between organic agriculture and soil health in the Atlantic Coastal Plain. In addition, a principal component analysis (PCA) will be conducted on the measured soil health indicators. Evaluation: Utilizing a previously used scoring scheme as a baseline, we will then identify indicators that account for the majority of the cumulative variability and will use a weighted mean to develop a more regionally representative soil health report. In this study, length of time from transition will be the metric of comparison. Research Station 3-yr Transition Experiment We propose a field experiment designed to evaluate the impact of using increasingly recalcitrant C material on SOC and soil health indicators during the transition period from conventional to organic. The most labile C input will be the inclusion of grass and legume cover crops within the rotation, followed by a compost, a compost and biochar mix, and lastly biochar alone. In addition, we evaluate the potential benefit of applying a single large application of amendment as compared to annual application over the 3-year transition period. By creating a 3x2x2 factorial design we will be able to determine the efficacy of individual C input strategies (timing, source) and the potential synergistic effect of combining inputs with the presence of cover crops on SOC and soil health. In addition, a no amendment treatment will serve as a control. Deep core samples (1 m) taken at the end of the 3-yr since transition will be identical to the samples taken in the chronosequence.The underlying croping rotation used in this study will be a corn-sweet potato-soybean rotation, a second cropping rotation incorporates winter cover crops, with the same summer crops ((Crimson Clover) - Corn - (Crimson Clover) - Sweet Potato - (Rye) -Soybean)). The field sites will enter organic management in the fall with planting of crimson clover. The organic amendments include: a yard waste certified compost, a pine based biochar, and a 50/50 mix of compost and biochar. The composted material will be applied at 75 t ha-1 in a single application or 25 t ha-1 per year for 3 years. The compost/biochar treatment will be mixed (50% Compost/50% Biochar) based on C concentration. The biochar treatment will be applied at the same C rate as the compost, and annual application treatments will again be split evenly between three years.The certified organic compost will be composed of predominantly yard waste feedstock, with woodchips as a bulking agent sourced from a commercial composting operation. Chemical composition of the composts will be analyzed every year for Total CHN and submitted to the NCDA&CS laboratory for a standard waste analysis. The biochar material will be sourced from a pine feedstock. The biochar will be characterized following the ASTM D1862-84 Standard Test Method for Chemical Analysis of Wood Charcoal.Background soil samples will be taken at the same depth increments as in the chronosequence sampling within each block (n=4 per site) prior to study initiation. These samples will be analyzed for total C and N and the same soil health parameters outlined in the chronosequence. Surface soil samples will be taken (0-15 cm) and submitted for routine soil fertility analysis. At planting, surface soil samples will be collected (0-15 cm) and analyzed for potentially mineralizable N (PMN) via incubation. The PMN values will allow an estimate of in-season N release to the crop. At harvest in Yr. 1 and Yr. 2, surface soil samples will be collected (0-15 cm) an analyzed for the suite of soil health metrics a with the exception of total C and N. Evaluation: After harvest of the soybean in Yr. 3, deep soil cores will be collected from all experimental units and analyzed for all soil health indicators as well as total C and N and compared to values of varying aged organic farms to determine the success or failure of this approach to rapid soil health improvement.All soil health parameters, SOC, above ground biomass, harvestable yield will be analyzed using generalized linear mixed models. Soil health results derived from the field study will be compared to those from the chronosequence by plotting results on the regional chronosequence graphs after 3 years and via one-way ANOVA of aggregated sites by age. Using PCA we will determine weighted soil health indicators, as described in the chronosequence methods and create a minimum dataset to remove highly correlated parameters. Effort: Correlation and multiple linear regressions between crop yields and the minimum dataset soil health indicators will be completed. We will also compare the PCA and weighting estimates with the long-term on-farm sampling and assess the similarity or difference of the rapidly changed soil health indicators compared to the long-term. Evaluation: The goal is to improve correlations so regionally important soil health indicators have a more meaningful connection with yield. Progress 09/01/23 to 08/31/24 Outputs Target Audience:During this reporting period we engaged with the following audiences: • Research scientist focused on sustainable agriculture and soil carbon sequestration • Agricultural and soil science students Changes/Problems:None to report. The NCE provided has allowed us to finish analyzing this major data set and give the the researchers and graduate students time to synthesize and produce impactful mansucripts. As mentioned in previous progress reports, supplies for this research far exceeded expectations in part due to inflation, sourcing and underestimation of soil health analysis costs. However, overall budgets are fine. What opportunities for training and professional development has the project provided?The undergraudate andgraduate students participating in the grant have been trained on the NRCS recommended soil health parameters, which has included collaborations with different labs and experiencing new techniques and a more fundamental understanding of soil processes. These students have presented their research in November of 2024at the national ASA-SSA-CSA meetings. How have the results been disseminated to communities of interest?The results were disemmenated at the ASA-SSSA-CSA Meetings. See abstract below. Teasley, F., Woodley, A., Heitman, J. L., Ricker, M. C., Kulesza, S. B., & Suchoff, D.(2024) Why Do Soil Health Indicators Vary in Response to Management Practices? \Abstract\. ASA, CSSA, SSSA International Annual Meeting, San Antonio, TX. https://scisoc.confex.com/scisoc/2024am/meetingapp.cgi/Paper/158554 What do you plan to do during the next reporting period to accomplish the goals? We are holding a half-day soil carbon sequestration workshop at the Organic Commodities and Livestock Conference (OCLC) on March 4th to discuss findings from these experimentsl. This also includes partcipation from RAFI for project evaluation and farmer feedback. We will present this work at the organic field day in the summer of 2025 Manuscripts will be submitted and the graduate student affiliated with this project on target to graduate summer 2025 Researchers will dissemenate at regional and national meetings and extension worksheets will developed in Q2 of 2025. Impacts What was accomplished under these goals? This region of the Southeast has low soil carbon and soil health parameters due to hot humid conditions and coarse textured soils. Despite these challenges soils of the same type found under forested conditions show significantly higher soil carbon content suggesting that improvements are possible. Organic management often relies on greater carbon inputs (manure, cover crops etc.) that conventional farming, which may result in accrual of soil health benefits over time. However, these changes often take years to become detectable in the soils and producers are interested in more immediate soil health benefits. The focus of this research is two pronged. The first goal is determine the innate potential that organic management has on the improving soil health and soil carbon over time. A chronosequence will be used to measure organic farms that have transitioned over a range of times (1-yr, 5-yr 15-yr etc) to determine the rate of soil health improvements with typical organic management. The second goal is to evaluate various carbon input strategies during the transition phase to organic, such as using cover crops, biochar or composts or in combination. At the end of the transition we will measure the soils for carbon and soil health parameters and compare them to the chronosequence to determine if we can more rapidly improve soil health outcomes for the immediate benefit of farmers considering to transition to organic management. We have completed the chrono sequence portion of the study where we evaluated organic farms in transition ranging from 1-15 years to examine the accrual rate of soil carbon and soil health on high disturbance, low carbon soils found in the coastal plain of the south east. A major finding fromthe chrono sequence carbon accrual can occur in these soils in forested systems that have been out of agriculture for 40-50 years. This establishes that climatic conditions are not the only cause of the low organic C in coastal plains soils rather it is agricultural activities. Importantly, the act of organic farming does not increase soil carbon over time. The farms we sampled were only constrained by soil type and it being row crop farming. Allowing for variation in farmer decision making within the bounds of organic certification. Within those bounds even with sustainability requirements we did not see evidence of carbon accrual. In contrast the carbon additions and cover cropping from the research station plot experiments showed increases in soil carbon above the surrounding regions conventional and organic farms sampled. This importantly highlights that there needs to intentional strategies for carbon building within organic management in this region if the farmers are to realize carbon build up goals. We have completed all field activities, soil health analysis and lab activities for the 2nd goal with the carbon additions from the research station experiments. Notable findings include that appears to be additionality when combining cover cropping with carbon amendments in when it comes to carbon concentrations in the soil. Specifically, the carbon derived from the cover crops is more protected when in the presence of a stable carbons source (ie biochar, compost). The is more biological soil health activity when compost is added compared to biochar. In the 3-years after addition of C there does not appear to be an immediate decline in carbon levels over that time period, suggesting some mid-term level of stability. Despite matching soil types subtle differences in the research station sites caused one site to more rapidly process cover crop residue. This had in-season implications on nitrogen status during the growing season and important insight on cover crop management and expectations despite seemingly similar fields. Yields were differentially impacts by cover crops and amendments. In some years, cover crops caused a decline in yields. This was not due to poor emergence as the sites are heavily tilled but due to increased weed pressure from the increased available nitrogen in the legume cover crop treatments. When cover crops were co-applied with biochar, we did not observe this yield decline due to what appears to be a temporarily immobilization of N during that critical weed free period in crop growth showing again a level of synergy when stacking practices. We are now in the process of finalizing data synthesis and several manuscripts based of the chrono sequence work and the research station plot experiments. Lastly, a new faculty member Mallory Choudior was sucessful in a New InvestigatorUSDA-NIFA grant focused on continuing the research station plot experiments in a study titled \"Cultivating Resilience: Evaluating Organic Amendments for Optimizing Soil Microbiome Functions\". This will leverage this study by evaluating the impact of these trials in the mid-term (3-5years) on the soil microbiome, greatly increasing knowledge that this grant established for growers. Publications Progress 09/01/22 to 08/31/23 Outputs Target Audience:During this reporting period we engaged with the following audiences: • Organic farmers whose land was sampled for the soil health soil carbon sequestration accural portion of the study • Research scientist focused on sustainable agriculture and soil carbon sequestration • Agricultural and soil science students, including a seminar presnetation and poster presentation by graduate students associated with the project Changes/Problems:A PhD student has switched theirprogram after 2-years to an MR degree. This has left some of the data interpretation to fall onto the PIs. However this will not impact the completness of the objectives and goals, but represents a delay in processing some of the analysis.Overall project is on track and no fundamental issues to report. What opportunities for training and professional development has the project provided?The graduate students participating in the grant have been trained on the NRCS recommended soil health parameters, which has included collaborations with different labs and experiencing new techniques and a more fundamental understanding of soil processes. In addition, one new PhD student has been trained on UAV and thermal sensor technology for deeper interpretation of the research station study. These students havepresented their research at regional meetings and in November of 2023 will present findings at the national ASA-SSA-CSA meetings. The ORG-OREI meeting in Washington allowed for a networking oppertunity for PI-Woodley with a likley outcome being furture collaboratios and grant writing with organic researchers within the U.S. How have the results been disseminated to communities of interest? This research is a central focus of two lectures in SSC 427 a undergraduate sustainable soils course taught by Alex Woodley. In addition, one PhD student presented their research at departmental seminar. The 2nd graduate student presented a poster on the carbon potential of these soils and a state level soil science conference. PI-Woodley presented preliminary findings at the ORG-OREI PI meetings in spring 2023 in Washington DC. After year 3 of the tranistion study is completed will present this research at field days, regional and national meetings. In addition at the end of year 3 we will be hosting a soil carbon building workshop. What do you plan to do during the next reporting period to accomplish the goals?The next period is for the completion of the study. This includes final harvest of the 3-year transition study, subsequent deep core soils sampling and analysis for soil health and soil carbon parameters. The chrono-sequence samples will be finished analyzing for soil health parameters and a chrono-sequence accrual rate will be determined based on time under organic management. This will include interpretation of how close if at all organic management can increase these parameters towards undisturbed forested systems. The results for the rapid health transition study will be compared to the chrono-sequence to evaluate potential to quickly elevate soil health outcomes. We will hold a half-day soil carbon sequestration workshop after the half-day state organic field day to disseminate results from to the growers. The research will be disseminated at national meetings, extension fact sheets and journal articles. Impacts What was accomplished under these goals? This region of the Southeast has low soil carbon and soil health parameters due to hot humid conditions and coarse textured soils. Despite these challenges soils of the same type found under forested conditions show significantly higher soil carbon content suggesting that improvements are possible. Organic management often relies on greater carbon inputs (manure, cover crops etc.) than conventional farming, which may result in accrual of soil health benefits over time. However, these changes often take years to become detectable in the soils and producers are interested in more immediate soil health benefits. The focus of this research is two pronged. The first goal is to determine the innate potential that organic management has on improving soil health and soil carbon over time. A chronosequence will be used to measure organic farms that have transitioned over a range of times (1-yr, 5-yr 15-yr etc) to determine the rate of soil health improvements with typical organic management. The second goal is to evaluate various carbon input strategies during the transition phase to organic, such as using cover crops, biochar or composts or in combination. At the end of the transition we will measure the soils for carbon and soil health parameters and compare them to the chronosequence to determine if we can more rapidly improve soil health outcomes for the immediate benefit of farmers considering to transition to organic management. In the last few years prices of fertilizer have been volatile and improving soil health and incorporating cover crops and subsequently potentially reducing inputs will be of increased interests to not only organic farmers but conventional growers as well. In the third year of this study (2022-2023) the group is in the final year of the 3-year transition study at two research stations in the coastal plains of North Carolina both on the Norfolk Sandy Loam. This is the same soil type that will be sampled on-farm from organically managed lands. In year 3, surface soil samples were collected for yearly changes in soil carbon and soil health. A crimson clover cover crop was grown in fall of 2022 and terminated into a sweet potato \"Covington\" crop in spring of 2023. In the spring carbon inputs (biochar and compost) were applied to the site. Data from this second field season is partially analyzed. However, in year 1 and 2 in corn and soybean phase there appears to a be a limited response to these various carbon inputs from a yield perspective. However, the cereal rye cover crop that was terminated in spring 2022, showed increase biomass in the presence of biochar or composts compared to the control at one of the two sites. During the reporting period we analyzed surface (0-15cm) soils for total carbon. We found the cover crops, biochar and composts all increased soil carbon compared to the control. The two carbon sources (biochar and compost) were not significantly different from one another in their ability to raise carbon levels. Interestingly, it appears that the presence of a carbon amendment increases the carbon signal from the cover crop. Suggesting some protective properties of having a carbon rich amendment present in an inherently low carbon soil. In addition, we have collected all the chrono sequence soil from farms ranging in transition to organic from 1 year to 15 years. Much of the soil analysis is ongoing. When comparing 40-50-year forested systems to arable land on the same soil type we preliminary data shows greater bulk density, higher pH, lower EC, lower carbon (43%) in cultivated fields compared to forested sites. This confirming our belief that despite the relatively low soil carbon content in this region there is still opportunity to improve carbon stocks through strategic soil management. For the specific objectives stated above the following as been accomplished. Sampling and analysis of soil carbon completed. Complementary soil health parameter analysis on-going. Preparation for manuscript in early 2024. Collection complete, analysis on going, with soil carbon analysis completed and interpretation on-going Planting of year 3 sweet potato completed, fields are well maintained and yields look promising. After harvest the intensive 1m soil sampling will occur. Publications Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Amhed, T., J. Heitman, A.L. Woodley and M. Ricker. 2023.Quantifying Soil Carbon Stocks and Soil Health Metrics in the Southeastern Coastal Plain. Soil Science Society of North Carolina. Annual Meetings, Raleigh NC. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:During this reporting period we engaged with the following audiences: • Organic farmers both in the region of study • Research scientist focused on sustainable agriculture and soil carbon sequestration • Agricultural and soil science students Changes/Problems:In the previous reporting period it was mentioned that we have a PhD student leave shortly after arriving due to personal reasons. We were only able to fill that position in July 2022. The current PhD student has been deeply engaged in the research but we have the 2021 soil samples still be analyzed so we are backlogged on processing due to the delay. We have hired undergrad assistants for the winter of 2023 to help support the processing and plan to be caught up by the time the field season starts. Some soil health capacity was lost with a faculty member leaving whose equipment we were planning on using, this has required PI Woodley's lab to purchases lab equipment to accomplish these soil health tests and has increased supplies cost more than expected but we still remain within the overall grant budget but may need to re-distribute funds. Overall project is on track and no fundemental issues to report. What opportunities for training and professional development has the project provided? The graduate students participating in the grant have been trained on the NRCS recommended soil health parameters, which has included collaborations with different labs and experiencing new techniques and a more fundamental understanding of soil processes. In addition, one new PhD student has been trained on UAV and thermal sensor technology for deeper interpretation of the research station study. In the following year these students will present their research at regional and national meetings, but currently are still generating presentable data. How have the results been disseminated to communities of interest?This research is a central focus of two lectures in SSC 427 a undergraduate sustainable soils course taught by Alex Woodley. After year 3 of the tranistion study is completed will present this research at field days, regional and national meetings. In addition at the end of year 3 we will be hosting a soil carbon building workshop. What do you plan to do during the next reporting period to accomplish the goals?We have all of the baseline conventional and forested sites soils collected and processed. We have also collected all of the chronosequence soils from organic farms across the coastal plain. The goal now is it analyze all this soils for total carbon and soil health parameters in the lab. The PhD student associated with this portion of the grant has finished most of their coursework and is focused solely on getting this accomplished. For the research station transition study we are entering our 3rd year of the study, where we will again measure cover crop biomass in the spring and plant the cash crop. We will take spring and mid-season soil samples and at the end of the season we will take deep core soil samples which align with the chronosequences data to be able to make an assessment on how far these soils have \"improved\" compared to established organic plots.In addition, soil health and soil carbon parameters will be analyzed from year 1 and year 2. **Impacts** What was accomplished under these goals? This region of the Southeast has low soil carbon and soil health parameters due to hot humid conditions and coarse textured soils. Despite these challenges soils of the same type found under forested conditions show significantly higher soil carbon content suggesting that improvements are possible. Organic management often relies on greater carbon inputs (manure, cover crops etc.) than conventional farming, which may result in accrual of soil health benefits over time. However, these changes often take years to become detectable in the soils and producers are interested in more immediate soil health benefits. The focus of this research is two pronged. The first goal is determine the innate potential that organic management has on the improving soil health and soil carbon over time. A chronosequence will be used to measure organic farms that have transitioned over a range of times (1-yr, 5-yr 15-yr etc) to determine the rate of soil health improvements with typical organic management. The second goal is to evaluate various carbon input strategies during the transition phase to organic, such as using cover crops, biochar or composts or in combination. At the end of the transition we will measure the soils for carbon and soil health parameters and compare them to the chronosequence to determine if we can more rapidly improve soil health outcomes for the immediate benefit of farmers considering to transition to organic management. In the last year prices of fertilizer inputs of increased dramatically and improving soil health and incorporating cover crops and subsequently potentially reducing inputs will be of increased interests to not only organic farmers but conventional growers as well. In the second year of this study (2021-2022) the group continued the 3-year transition study at two research stations in the coastal plains of North Carolina both on the Norfolk Sandy Loam. This is the same soil type that will be sampled on-farm from organically managed lands. In year 2, surface soil samples were collected for yearly changes in soil carbon and soil health. A cereal rye cover crop was grown in fall of 2021 and terminated into a soybean crop in spring of 2022. In the spring carbon inputs (biochar and compost) were applied to the site much of the data from this second field season is still being analyzed and currently we cannot make any definitive statements on the efficacy of these various organic transition strategies. However, in year 1 in corn there appears to a be a limited response to these various carbon inputs. In addition, we have collected all the chronosequence soil from farms ranging in trasnsition to organic from 1 year to 15 years.. Much of the soil analysis is ongoing. Preliminary data shows that there is a significant difference between soil carbon content in forested systems compared to conventional farmed soils, confirming our belief that despite the relatively low soil carbon content in this region there is still opportunity to improve carbon stocks through strategic soil management. Of the specific objectives stated above we have accomplished the following: 1.)Establish baselines of mean soil C stocks for conventional agricultural fields and mature secondary growth forest stands on the Atlantic Coastal Plain All field collection is complete, soil processing is complete and total carbon and nitrogen analysis is ongoing, including soil health parameters. 2)Evaluate the long-term effects of organic agriculture (>15 years) on soil C and related soil health metrics using Chronosequence methods. All field collection is complete, soil processing is ongoing and soil analysis will begin in January of 2023. 3) Evaluate carbon (composts, bio char, cover crop biomass) input strategies during a 3-year transition period in a high disturbance crop rotation on soil organic carbon, soil health indicators and crop yields. Year 2 was successfully conducted with representative yields of both soybean and the cover crop cereal rye grown at the two research stations. Crop quality and yield are being assessed. Soil samples were taken consistent with year 1. Surface soil health analysis is to be conducted the January-April. Fall cover crops (crimson clover) were successfully planted in fall of 2022 for the next season's crop. **Publications** **Progress**

09/01/20 to 08/31/21 **Outputs** Target Audience:During this reporting period we engaged with the following audiences: Organic farmers both in the region of study Research scientist focused on sustainable agriculture and soil carbon sequestration Agricultural and soil science students Changes/Problems: One of the PhD students that started on this project had to leave after only being on for 2 months due to unforeseen circumstances not related to this research, the graduate program or the department. The position has yet to be filled but we are hoping to have a student in the position in the early spring 2022. The cost of the biochar exceeded what was originally budgeted and we will need to adjust the budget to account for the unanticipated expense What opportunities for training and professional development has the project provided? We trained 3 undergraduate summer students on experimental design, field soil sampling and lab soil health analysis One graduate student has been trained on deep-core soil sampling and lab soil analysis One graduate student was trained on UAV and image capture for further interpretation of the research station study results A Research Experiences for Undergraduates (REU) student was mentored by Alex Woodley and a PhD student on basic field research using this field experiment as part of the experience How have the results been disseminated to communities of interest? Presented the transition study at the North Carolina State University Organic Field Day August 2021 - 75 people Presented work from this project at a researcher and farmer focused Webinar titled \"Farming for Ecological Outcomes\" - 60 people This research is a central focus of two lectures in SSC 427 a undergraduate sustainable soils course taught by Alex Woodley What do you plan to do during the next reporting period to accomplish the goals? Continue the transition study, which will be in soybeans summer of 2022. Including cover crop termination and biomass sampling Carbon input application Soil Sampling Soybean Harvest and Yield/Quality Determination Begin the on-farm organic field sampling starting in winter of 2022 to develop the chronosequence as stated in the accomplishment section Continue to present and field days and incorporate data into the SSC 427 course **Impacts** What was accomplished under these goals? This region of the Southeast has low soil carbon and soil health parameters due to hot humid conditions and coarse textured soils. Despite these challenges soils of the same type found under forested conditions show significantly higher soil carbon content suggesting that improvements are possible. Organic management often relies on greater carbon inputs (manure, cover crops etc.) that conventional farming, which may result in accrual of soil health benefits over time. However, these changes often take years to become detectable in the soils and producers are interested in more immediate soil health benefits. The focus of this research is two pronged. The first goal is determine the innate potential that organic management has on the improving soil health and soil carbon over time. A chronosequence will be used to measure organic farms that have transitioned over a range of times (1-yr, 5-yr 15-yr etc) to determine the rate of soil health improvements with typical organic management. The second goal is to evaluate various carbon input strategies during the transition phase to organic, such as using cover crops, biochar or composts or in combination. At the end of the transition we will measure the soils for carbon and soil health parameters and compare them to the chronosequence to determine if we can more rapidly improve soil health outcomes for the immediate benefit of farmers considering to transition to organic management. In the last year prices of fertilizer inputs of increased dramatically and improving soil health and incorporating cover crops and subsequently potentially reducing inputs will be of increased interests to not only organic farmers but conventional growers as well. In the first year of this study the group has established the 3-year transition study at two research stations in the coastal plains of North Carolina both on the Norfolk Sandy Loam. This is the same soil type that will be sampled on-farm from organically managed lands. Study initiation included background deep soil sampling for baseline carbon stocks and planting of cover crops in fall of 2020. In the spring carbon inputs (biochar and compost) were applied to the site and corn planted. Soils were also sampled during the growing year and at harvest. Much of the data from this first field season is still being analyzed and currently we cannot make any generalized statements on the efficacy of these various organic transition strategies. In addition, we have collected baseline soil samples from secondary regrowth forests and other conventional fields to determine upper and lower boundaries of soil carbon and soil health parameters. Much of the soil analysis is ongoing. Preliminary data shows that there is a significant difference between soil carbon content in forested systems compared to conventional farmed soils, confirming our belief that despite the relatively low soil carbon content in this region there is still opportunity to improve carbon stocks through strategic soil management. In our first year of the study initiation we accomplished or initiated the following objectives. We sampled soils to establish baselines of mean soil C stocks for conventional agricultural fields and mature secondary growth forest stands on the Atlantic Coastal Plain. The soil carbon and soil health lab analysis is still ongoing Objective 2 - Sampling initiating Winter 2022 Established the 3-year transition study at two locations in the coastal plains of NC (Upper Coastal Research Station and Horticultural Crops Research Station), this includes: Sampling down to 1m for background stocks of soil carbon and soil health parameters Planting cover crop treatments in fall of 2020 Applying the carbon inputs (Biochar and Composts) to fields in Spring 2021 and planting corn Sampling corn yields and soil samples from field at harvest Fall 2021 Planting cover crops for season 2 in Fall 2021 Ongoing: soil carbon and soil health analysis from first field season Ongoing: Statistical evaluation **Publications**

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Diversifying Organic Inputs to Improve Soils Supporting Organic Vegetable in Southeastern Usa

Accession No.	1023647
Project No.	SC-2020-02281
Agency	NIFA SC.\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51106-32363
Proposal No.	2020-02281
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Grant Year	2020
Investigator(s)	Ye, R.

NON-TECHNICAL SUMMARY

Increasing demands for organic vegetables has created high-value opportunities for conventional producers to transition to organic in southeastern states of USA, where the organic production acreages lags nations\' leading states. However, growers in the region are facing unique challenges in soils (i.e. low soil organic carbon, meager soil fertility, and poor soil structure). Increasing organic inputs (e.g. manure, compost, and cover crop), along with conservation tillage, is considered one of the best management strategies to address such soil health issue; yet the diverse organic sources and their distinguished physio-chemical properties, in combination with various management practices across spatial and temporary scales, may make desired economic and environmental outcomes less predictable. The objective of this project is to address whether this diversity in organic inputs can be managed to improve underground biodiversity and soil functions underpinning soil health and the productivity of organic vegetables in southeastern soils (mostly Ultisols), and whether tillage affects the outcomes. Through field and laboratory studies, we plan to characterize and understand the interactive effects of diversifying organic inputs and tillage on microbial community structure and composition, soil C dynamics, nutrient processes and availability, changes of soil health, and the yield and nutritional quality of organic vegetables. The goal is to advance our knowledge of soil biogeochemical processes that are important to the productivity, profitability, and sustainability of organic vegetables, providing research-based information to regional producers to improve ecosystem services and environmental stewardship of their farms. This project combines expertise from Clemson University and Rodale Institute, while integrating research, education, and extension activities, to address the USDA NIFA Organic Transitions program\'s Priorities 1 and 2 through strong partnerships.

OBJECTIVES

The long-term goal is to formulate management strategies to increase the productivity and profitability of organic vegetable production while improving the ecosystem services and environmental stewardship. Through the collaboration between Clemson University and Rodale Institute Southeast Organic Center, field-based research will be conducted in South Carolina and Georgia to create models for organic vegetable production that are financially profitable in the Coastal Plain of southeastern USA. The transdisciplinary research, extension, and educational activities will address the questions established in the following supporting objectives, directly addressing the Priorities 1 and 2 described in the USDA NIFA Organic Transitions Request for Applications (RFA) for Fiscal Years (FY) 2020:1. Evaluate how diversified organic inputs interact with tillage affecting soil microbial diversity and the functional groups associated with soil organic carbon (SOC), nitrogen (N), and phosphorus (P) cycling 2. Quantify the interactive impacts of diversified organic inputs and tillage on (a) C, N, and P biogeochemical processes and (b) short-term changes of soil health 3. Evaluate how diversified management influences nutritional quality and yields of the vegetables 4. Provide a transdisciplinary pedagogical framework that delivers enhanced educational opportunities for undergraduate/graduate students 5. Disseminate research-based knowledge to promote the adoptions of diversifying management practices

APPROACH

Experimental design: The goal is to diversify the source, quantity, and introduction methods of organic inputs to improve soils and agronomic production in organic vegetables. Cover crops and manure applications will be introduced along with either conservation (strip-till) or conventional tillage to create the gradients of organic input diversity. The experiment will be a randomized complete block split-plot design with tillage as the main plots with cover crop and composted poultry manure treatments randomly embedded. The factors are composted poultry manure amendment (with and without), cover crop (cereal rye, hairy vetch, cereal rye plus hairy vetch, and no cover crop control), and tillage (conventional and conservation) with four field replicates. It is assumed that mono- and bi-culture of the cover crops result in varied amounts of biomass inputs with different C to N ratios. Along with composted manure amendment and tillage, this design diversifies organic inputs in sources (manure or plant residues), physio-chemistry (C to N ratio), rates (absolute biomass inputs), and introduction methods (left in soil surface or incorporated into soils by tillage). Field operation: The field work will be conducted simultaneously in certified organic farms at the Pee Dee Research and Education Center, Florence, SC, and Rodale Institute Southeast Organic Center, Chattahoochee Hills, GA, accounting for variations in climatic and edaphic factors. The rotation will be tomato-cucumber-winter cover crop. Tomato will be planted in April, followed by cucumbers after the harvest, and managed according to the Southeastern U.S. 2019 Vegetable Crop Handbook. Cereal rye and hairy vetch will be drill-seeded at 60- and 15-pounds acre-1, respectively, while their mixture will be drill-seeded at 30 pounds of cereal rye with 8 pounds of hairy vetch per acre. Cover crops will be terminated with a roller-crimper. Activities: We will determine how diversified organic inputs interact with tillage to change the diversity and composition of soil microbial communities and microbial functional groups that associated with C, N, and P cycling (Objective 1). The distribution and stability of organic inputs in various soil pools and decomposition patterns will be estimated (Objective 2a). Nitrogen and P pools, availability, transformation, leaching potentials, and use-efficiency will be determined (Objective 2a), while changes in various soil health attributes, e.g. soil structure, bulk density, and water holding capacity, nutrient availability, microbial respiration, enzymatic activities, and nutrient mineralization potentials will be evaluated (Objective 2b). Yield and nutritional quality of vegetables will be monitored (Objective 3). Students will be recruited and trained during the entire grant period (Objective 4). Field days, workshops, presentations, and publications will be arranged to dissimilate research-based information to a wide range of audiences (Objective 5).Data analyses and interpretation: Measured environmental and soil variables will be evaluated for their relative effects on vegetable yields and nutritional contents with the stepwise regression model. Multivariate analyses, e.g., principal component analysis (PCA) and canonical correlation analysis (CCA), will be performed to explore and detect the interdependence of microbial properties and soil biogeochemical variables across the treatments. Microbial diversity will be calculated as described previously. Cornell comprehensive assessment of soil health (CASH) will be applied to identify treatment impacts on changes in soil health. The relationship among organic inputs diversity, soil health index, microbial diversity, and soil functions will be estimated with correlation analysis. Microbial diversity data (Objective 1) will be used to evaluate the interactive impacts of organic diversity and tillage on microbial community composition, diversity, and the functional groups associated with C, N, and P cycling, which will be also used to identify changes of soil biological health and the associated soil functions (nutrient cycling, C sequestration, nutrient and water retention, soil structure maintenance). Data of soil C dynamics (Objective 2a) will be used to highlight the benefits of optimal organic amendments (e.g. rates, types, and methods) and reduced tillage in increasing SOC, while reducing nutrient losses, which will be further demonstrated by the assessment of soil health changes (Objective 2b), and nutrient use-efficiency and vegetable yields (Objective 3). All data will be integrated to describe the agronomic and environmental outcomes of diversifying organic inputs. These integrated comprehensive data will address the fundamental question of whether and how organic inputs can be optimized along with tillage to improve soil health, environmental outcomes, and agronomic production in sandy Coastal Plain soils keeping organic vegetables productive, profitable, and sustainable. Evaluation of outputs: A combination of formative and summative evaluation will be conducted to monitor and evaluate the progress, quality, and effectiveness of the activities implemented and products generated. Monthly project meetings will be held to review project activities and methods, including the design of data collection, data analyses, and communication of findings. Evaluation research is woven into each objective and will include regular stakeholder involvement in reviewing and refining project activities and communications. Research findings of this study will be disseminated via peer-reviewed journal articles, extension publications, and press releases. The citation rating for the journal articles and the number of times the information is accessed or downloaded will be monitored. Extension activities will be evaluated by surveying the audiences with inquiries including program quality, how well the information was received, and how the knowledge was used for adjustments of their management practices. The education activities will be embedded in research activities and vice versa, especially the learning and application of experimental skills and knowledge. The competitiveness of the students will be evaluated with the National Postdoctoral Association Core Competencies Self-Assessment Checklist. Progress 09/01/20 to 08/31/24 Outputs Target Audience:The target audience includes but is not limited to, University students, extension specialists, organic farmers, stakeholders, and the public. We leveraged the strength of Clemson University as a land grant university and Rodale Institute to disseminate research-based knowledge to the target audience by using the two institutions\' extensive extension networks. In addition, results were delivered to the academic and professional communities through publications in peer-reviewed journals and presentations at professional conferences. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project provided funding and salary support for two graduate students to complete their graduate training. Meanwhile, the project provided field and experimental plots to support the dissertation research of a third graduate student. Research committees were organized for each graduate student. Regular meetings were organized to discuss research issues and progress. The students were supervised and trained throughout their research on this project. In addition, the students were provided travel grants to participate in various academic and professional meetings. The project also offered hands-on research experience for four high school students. How have the results been disseminated to communities of interest?We took advantage of the extensive extension network of Clemson University and Rodale Institute to disseminate the research outcomes. Field day demonstrations, virtual seminars, newsletters, and social media were fully utilized to transmit the research-based information. Presentations at academic conferences and publications in peer-reviewed journals have also been used. More details can be found in the above sections. In addition, the team advertised and delivered the significance of organic agriculture to the public by organizing an in-person workshop, participating in elementary schools4H activities, broadcasting an interview from a local radio station, and donating project vegetables to a local food bank. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Obj. 1: Quantified diverse organic inputs and evaluate how the inputs affect soil microbial communities To estimate the cover crop production potential, aboveground biomass was collected weekly or biweekly during the whole winter season and weighted. The biomass data were then used to develop a growth model. The model suggested that to maximize cover crop biomass production, fertilization or adjusting plating and termination timing (allowing maximal growth duration) may be essential. Soil DNA was extracted. 16S and ITS rRNA sequencing were also conducted. The abundance of N cycle functional genes was also determined by qPCR. Both cover crops and manure application increased N availability but posed limited and distinct short-term effects on soil microbial communities. For instance, 1) only manure compost application resulted in higher fungal abundance; 2) when compared to the control, manure compost increased the abundance of ammonia-oxidizing archaea (AOA) only in the mixture of rye and vetch; 3) vetch plots had a higher abundance of ammonia-oxidizing bacteria (AOB) than other cover crop plots. Continue organic inputs from cover crop residues and manure compost had limited and inconsistent impacts on microbial alpha diversity compared to the control during the experiment. However, the inputs from the rye (nonlegume cover crop) posed different impacts on microbial diversity than the vetch (legume cover crop). In addition, the inputs from cover crops and manure composts modified microbial community composition and structure, positively correlated to soil inorganic N concentrations and cumulative N inputs. Main conclusions: 1) Cover crop biomass production potential can be estimated with growing degree day and soil N availability; 2) to improve positive cover crop impacts, increasing biomass production with fertilization may be necessary; 3) N availability is at least as important as organic substrate availability in regulating soil microbial communities in sandy soils; and 4) Cover crop impacts on soil microbial community is specie-specific, likely due to their difference in tissue biochemistry. Obj. 2: Quantify the interactive impacts of diversified organic inputs and tillage on soil biogeochemical properties and soil health Soil samples were analyzed for various soil physical, chemical, and biological health indicators associated with C, N, and P processes. Regardless of tillage practice, continuous annual cover cropping and manure compost application did not produce proportional responses in measured soil physio-biogeochemical properties. Generally, consistent positive responses were mainly observed for biological indicators during the cover crop growing season, highlighting the importance of cover crop root impacts. Regardless of tillage type, applications of manure compost and incorporation of cover crops did not result in higher active C concentrations and SOC content at the end of the experiment. Main conclusions: 1) increasing organic inputs by integrating winter cover crops cannot enhance SOC content and soil health, at least in the short-term; 2) compared with conservation tillage, conventional tillage did not result in decreased SOC content and soil health in the short-term, which was likely partially compensated by cover crop residue returns; and 3) managing SOC with diverse organic inputs alone may not improve the sandy soils effectively, where nutrients are commonly limited. Obj. 3: Evaluate how diversified management influences vegetable performance Vegetable yields were estimated by harvesting the yields in the middle row of each plot. Compared to conventional tillage, conservation tillage impeded vegetable growth, reducing the yields, especially for tomatoes. However, except for corn yield, neither cover crop incorporation nor manure compost application changed the vegetable yields. Regardless of manure compost application, vetch and its mixture with rye increased sweet corn yields. Cover crop biomass production was positively correlated to tomato yields in the 2022 and 2023 seasons, which was not observed for sweet corn and cucumber production. Main conclusions: 1) cover crop biomass production can be linked to vegetable yields; 2) excessive N availability can reduce vegetable yields; and 3) different vegetables can respond differently to the same management practices. Obj. 4: Provide a transdisciplinary pedagogical framework that delivers enhanced educational opportunities for undergraduate/graduate students Three graduate students were trained in this interdisciplinary project, covering soil biogeochemistry, microbial ecology, agronomy, and environmental sciences. They were encouraged and supported to present their research at the Agronomy Society of America-Crop Science Society of America-Science Society of America International Annual Meeting, AGU Annual Meeting, and American Society for Microbiology Annual Meeting. Four high school summer interns were recruited and trained through the collaborations between Clemson University and South Carolina Governor\'s School for Science and Mathematics. The hands-on experience provided an excellent opportunity for them to understand real-world challenges and the scientific ways to address them. Obj. 5: Disseminate research-based knowledge to promote the adoption of diversifying management practices We took advantage of the extensive extension network of Clemson University and Rodale Institute to disseminate the research outcomes. During the project, six field-day demonstrations were conducted in South Carolina and Georgia. One online seminar was delivered during the Covid-19 pandemic. Project information and progress were published and advertised in newsletters (e.g., Clemson Newsstand and Rodale Institute Newsletter), social media (e.g., LinkedIn and Instagram), and other online platforms (e.g., Vegetable Growers News). Research data and results were also presented at academic conferences and peer-reviewed journals. In addition, a group of scientists of the multistate research project NC1178 toured the research field at SC. Broad impacts: This specific project addressed whether/how diverse organic inputs can be managed along with conservation tillage to improve the health of the sandy Coastal Plain soils to support organic vegetable production. The research outcomes advance our knowledge and understanding of how standard management practices affect soil physio-biogeochemical processes critical to organic vegetables\' productivity, profitability, and sustainability. The extension and outreach outcomes provide research-based information to regional producers to improve ecosystem services and environmental stewardship of their farms and their quality of life. More specifically, the research provides an empirical model to optimize cover crop management (Obj. 1) for better environmental (Obj. 1&2) and agronomic (Obj. 3) outcomes (i.e., improved soil health with reduced resource inputs and increased production). The project cultivated well-trained personnel who will effectively work in soil sciences and relevant disciplines to explore and address the current agricultural and environmental challenges (Obj. 4). Meanwhile, the project provides information to optimize organic inputs and tillage to restore soil health and resilience in sandy Coastal Plain soils, keeping organic vegetables productive and sustainable (Obj. 5). Moreover, this project will increase public awareness of soil health and environmental literacy, encourages the participation of diverse groups to improve their environment and life of quality through research and education and help clientele and stakeholders to manage their soils and farms better while maintaining and improving environmental stewardship. Publications Type: Journal Articles Status: Published Year Published: 2024 Citation: Wang, Z., Saski, C., Williamson, C., Campbell, B., Ye, R., 2024. Crop cover and manure compost: Their varied effects on nitrogen availability and nitrogen cycling functional gene abundances in sandy soils for organic farming. Applied Soil Ecology 200, 105446. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Wang, Z., Ye, R., & Saski, C. (2023) Hairy Vetch and Manure Compost Enhanced Soil Nitrogen Availability and Altered Bacterial Community Structure in Organic Production. ASA, CSSA, SSSA International Annual Meeting, St. Louis, MO. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Oliver, F. E., & Ye, R. (2023) Carbon and Nitrogen Cycling As Influenced By Tillage, Cover Crops, and Manure in Organic Agriculture. ASA, CSSA, SSSA International Annual Meeting, St. Louis, MO. https://scisoc.confex.com/scisoc/2023am/meetingapp.cgi/Paper/153605 Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Wang, Z., Ye, R., & Saski, C. (2023) Hairy Vetch and Manure Compost Improved Soil Nitrogen Availability and Reduced Bacterial Diversity in Organic Vegetable Production ASA, CSSA, SSSA International Annual Meeting, St. Louis, MO. https://scisoc.confex.com/scisoc/2023am/meetingapp.cgi/Paper/151988 Progress 09/01/22 to 08/31/23 Outputs Target Audience:The target audience includes but is not limited to, University students, extension specialists, organic farmers, stakeholders, and the public. We will leverage the strength of Clemson University as a land grant university and Rodale Institute to disseminate research-based knowledge to the target audience by using the two institutions\' extensive extension networks. In addition, results will be delivered to the academic and professional communities through publications in peer-review journals and presentations at professional conferences. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Three graduate students were hired to work on this project. They were trained and supervised throughout their research. The students were provided travel grants to participate in the Tri-Societies

Annual International meeting. A high school summer intern from South Carolina Governor\'s School was recruited through Clemson University Summer Program for Research Interns. The student got hands-on experience in field and laboratory research. How have the results been disseminated to communities of interest?The disseminative efforts include: Field day demonstration was conducted at the 2022 Pee Dee REC Annual Field Day. We organized a field tour and onsite demonstration for a group of research scientists associated with the Multistate research project NC1178. Dr. Ye presented the project results in a Departmental seminar. More than 50 visitors from different organizations, companies, and universities toured the project at the GA site. These visitors included extension agents, university professors, students, schoolteachers, VPs of companies, consultants, and local farmers. The Southeast Organic Center was visited by Asst. Prof. Leonardo Bastos and his team from the University of Georgia in May 2023. We conducted a series of drone flights over cover crops. Post was shared on LinkedIn and Instagram. The LinkedIn post got 79 likes, 4 comments, and 6 reposts. The Instagram postreceived 2535 impressions, 101 likes, 1 comment, 1 share, and 2 saves. Rodale Institute publishedan electronicNewsletter on June 30 highlighting this research project, which has over 30,000 subscribers, half identifying as farmers or agricultural professionals (available online at mailchi.mp/rodaleinstitute/research-training-and-education-for-farmers-in-the-southeast). What do you plan to do during the next reporting period to accomplish the goals?We are completing the 2023 season with tomatoes. More analyses are scheduled. However, to make the search a two-full-cycle rotation, while minimizing the Covid-19 impacts, we requested a no-cost extension and got approval. We will continue to repeat the experiment at GA and SC sites following the procedures detailed in the granted proposal for the next reporting period. No major changes are expected. Major activities are described by objectives as follows. Objective 1:We will continue the molecular approaches on microbial communities, including PCR, DNA sequencing, and metagenomic analyses, to determine the abundance and diversity of specific functional groups and the composition and metabolic potentials of microbial communities. We will start to compare the treatment impacts across the GA and SC sites. Objective 2:We will use soil health assessment frameworks to evaluate short-term changes in soil health indicators in response to organic inputs and tillage. Objective 3: We will analyze the nutrient contents of the tomatoes and sweet corn and estimate the nutrient use efficiencies of the tomatoes and sweet corn under different management treatments. Objective 4: We will help the students to complete their dissertation research and present findings at professional meetings. More efforts will be focused on publishing the research data. Objective 5: We will prepare slides and handouts for presentations on field days, workshops, and academic conferences. Impacts What was accomplished under these goals? Issues being addressed: Increasing demands for organic vegetables has created high-value opportunities for conventional producers to transition to organic in southeastern states of the USA, where the organic production acreages lag nations\' leading states. However, growers in the region are facing unique challenges in soils, which typically have low soil organic carbon, meager soil fertility, and poor soil structure. Increasing organic inputs (e.g., manure, compost, and cover crop), along with conservation tillage, is widely considered one of the best management strategies to address such soil health issues; yet the diverse available organic sources and their distinguished physiochemical properties, in combination with various management practices across spatial and temporary scales, may make desired economic and environmental outcomes less predictable. The project aims to investigate the interactive effects of diversifying organic C inputs and tillage on soil microbial community, soil health, and organic yields in the context of improving the soils, plants, and the environment. What we did and potential impacts: Field experiments were carried out simultaneously at the Pee Dee Research and Education Center of Clemson University (South Carolina) and the Southeast Organic Center of Rodale Institute (Georgia). Organic inputs were diversified by planting different cover crops and their mixtures, along with manure application. Through field and laboratory studies, we investigated the interactive effects of diversifying organic inputs and tillage on soil microbial community composition, soil carbon dynamics, nutrient cycling, soil health, and organic yields. The goal is to advance our knowledge and understanding of how management practices affect soil physio-biogeochemical processes that are important to the productivity, profitability, and sustainability of organic vegetables, providing research-based information to regional producers to improve ecosystem services and environmental stewardship of their farms, and their quality of life. The field experiment will be repeated on the same site for three years. Progresses and accomplishments by objectives: The following describes research activities and accomplishments by objectives: Obj. 1: Evaluate how diversified organic inputs interact with tillage affecting soil microbial diversity and the functional groups associated with soil organic carbon (SOC), nitrogen (N), and phosphorus (P) cycling DNA samples were extracted from both SC and GA sties. qPCR was conducted to understand the abundance of bacteria, archaea, and fungi populations, as well as the N functional genes. Samples were also sent to commercial labs for sequencing. We are completing the analyses of sequencing data. Preliminary data (SC site) suggested, Both cover crops and manure did not change the abundance of bacteria and archaea communities. Manure application, but not cover crops, increased the abundance of fungi communities. In addition, the vetch plots had higher ammonia-oxidizing bacteria gene (AOB amoA) abundance than others, while manure application resulted in higher fungi abundance than the control plots. Planting hairy vetch decreased microbial diversity. Neither cover crop integration nor manure application changed the abundance of AOA-amoA, comammox clade A, comammox clade B, and nifH gene copies. Cover crop integration increased the AOB-amoA abundance, which, however, depended on the species. Higher AOB-amoA abundance was only observed in plots planted with VE when compared to the control plots. Obj. 2: Quantify the interactive impacts of diversified organic inputs and tillage on (a) C, N, and P biogeochemical processes and (b) short-term changes in soil health The preliminary results indicated limited impacts of cover cropping and manure application on the measured soil properties despite significantly different organic inputs, which however were not affected by tillage. Some examples of significant impacts include: Manure application increased soil EC, which was only observed in hairy vetch plots. Higher nitrate (NO_3^-) was found in the vetch plots when compared to the rye and control plots. Plots with manure application had higher ammonia (NH_4^+) concentrations than those without. The N-acetyl-β-D-glucosaminidase activity was higher in vetch plots than in rye and control plots and leucine aminopeptidase activities were higher in manure plots than in the non-manure plots. Regardless of manure application, cover cropping increased organic mineralization rates. Obj. 3: Evaluate how diversified management influences the nutritional quality and yields of the vegetables In the 2022 season, sweet corn was planted in both SC and GA sites. The SC data suggested both cover crop and manure application affected the yields, while tillage had no impacts. In general, manure application increased the yield. Planting cereal rye decreased corn yield, which however was not observed for the vetch and the mixtures of vetch and rye. The data in the GA site is being analyzed. Obj. 4: Provide a transdisciplinary pedagogical framework that delivers enhanced educational opportunities for undergraduate/graduate students One MS student completed his thesis research on this project and graduated. Two more Ph.D. students are still in training with dissertation research on Objectives 1, 2, and 3. One of the Ph.D. students will have his comprehensive exam scheduled in October 2023, while another one has his dissertation research approved by the advisory committees. The students presented their research at the 2023 Tri-Societies Annual Meeting, one of whom won 2nd place in the graduate student presentation competition. One high school summer intern participated in the project. Obj. 5: Disseminate research-based knowledge to promote the adoption of diversifying management practices The disseminative efforts include: Field day demonstration was conducted at the 2022 Pee Dee REC Annual Field Day. We organized a field tour and onsite demonstration for a group of research scientists associated with the multistate research project NC1178. Dr. Ye presented the project results ata Departmental seminar. More than 50 visitors from different organizations, companies, and universities toured the project at the GA site. These visitors included extension agents, university professors, students, schoolteachers, VPs of companies, consultants, and local farmers. The Southeast Organic Center was visited by Asst. Prof. Leonardo Bastos and his team from the University of Georgia in May 2023. We conducted a series of drone flights over cover crops. Post was shared on LinkedIn and Instagram. The LinkedIn post got 79 likes, 4 comments, and 6 reposts. The Instagram postreceived 2535 impressions, 101 likes, 1 comment, 1 share, and 2 saves. Rodale Institute publishedan electronicNewsletter on June 30 highlighting this research project, which has over 30,000 subscribers, half identifying as farmers or agricultural professionals (available online at mailchi.mp/rodaleinstitute/research-training-and-education-for-farmers-in-the-southeast). Publications **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: Research products/outcomes will be directed to graduate and undergraduate students, extension specialists, organic farmers, and the general public. Results will be delivered to the academic communities through publications in peer-review journals and presentations in professional conferences. We will leverage the strength of Clemson University as a land grant university and Rodale Institute to disseminate research-based knowledge to farmers, stakeholders, and the general publics by using the university's extension network. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Two graduate students were hired to work on this project. They were trained and supervised throughout their research. Another PhD student was hired with financial supports from Clemson University (will start in August 2022) to investigate the green house gases emission dynamics. This graduate student will take advantage of the established field plots and experimental settings to complete his dissertation. How have the results been disseminated to communities of interest?Due to the Covid-19 pandemic, in person extension activities were limited. This research project was presented to and discussed with local farmers on a field day at GA. The research was advertised to farmers, the public, extension agents, and academic communities through extension outlets of the Clemson University (e.g., Clemson News, extension handouts) and Rodale Institute (e.g., webinar and regular field tour). What do you plan to do during the next reporting period to accomplish the goals? Despite the legacy impacts and delays by the Covid-19 pandemic, we were able to implement the planned activities at both SC and GA sites in the past year. No major changes are expected. We will continue to analyze the data and follow the procedures detailed in the granted proposal for the next reporting period. Major activities are described by objectives as follows. Objective 1:we will continue the molecular approaches on microbial communities, including PCR, DNA sequencing, and metagenomic analyses, to determine the abundance and diversity of specific functional groups and the composition and metabolic potentials of microbial communities. Objective 2:we will use soil health assessment frameworks to evaluate short-term changes of soil health indicators in response to organic inputs and tillage (2020-2022). In addition to complete the analyses of soil carbon and nitrogen dynamics, we will conduct phosphorous fractionation analyses to investigate the distribution and stability of phosphorus introduced by manure application. Objective 3:We will prepare to analyse nutrient contents of the tomatoes from

2021 season and estimate nutrient use-efficiencies of the tomatoes under different management treatments. Sweet corn isgrowing in the field now. We will estimate the yield and nutrients of the corn after harvest and determine the nutrient use efficiency. Objective 4:We will help the MS student to complete his thesis writing and publish his research data. The PhD student will continue his dissertation research, especially the changes of microbial diversity and community compositions, while reporting research progresses and issues to his advisory committee. The newly hired PhD student will take advantage of the established field plots and experimental settings to start his dissertation research. An advisory committee will be organized to discuss the research and education plans. In addition, the students will spend some time in Co-PIs' lab to get some training on laboratory and analytical skills. Objective 5:We will prepare slides and handouts for presentations in field days, workshops, and academic conferences, e.g., 2022 Pee Dee REC Field Day and Southeast Organic Center Field Day. **Impacts** What was accomplished under these goals? Issues being addressed: Increasing demands for organic vegetable has created high-value opportunities for conventional producers to transition to organic in southeastern states of USA, where the organic production acreages lags nation's leading states. However, growers in the region are facing unique challenges in soils, which typically has low soil organic carbon, meager soil fertility, and poor soil structure. Increasing organic inputs (e.g. manure, compost, and cover crop), along with conservation tillage, is widely considered one of the best management strategies to address such soil health issue; yet the diverse available organic sources and their distinguished physiochemical properties, in combination with various management practices across spatial and temporary scales, may make desired economic and environmental outcomes less predictable. What we did and potential impacts: In this specific project, we tried to address whether this diversity in organic inputs (both quality and quantity) can be managed to improve underground biodiversity and the soil processes underpinning soil health and the productivity of organic vegetables in southeastern Ultisols, and whether tillage affects the outcomes. Field experiments were carried out simultaneously at Pee Dee Research and Education Center of Clemson University (South Carolina) and Southeast Organic Center of Rodale Institute (Georgia). Organic inputs were diversified by planting different cover crops and their mixtures, along with manure application. Through field and laboratory studies, we investigated the interactive effects of diversifying organic inputs and tillage on soil microbial community composition, soil carbon dynamics, nutrient cycling, soil health, and organic yields. The goal is to advance our knowledge and understanding of how management practices affect soil physio-biogeochemical processes that are important to the productivity, profitability, and sustainability of organic vegetables, providing research-based information to regional producers to improve ecosystem services and environmental stewardship of their farms, and their quality of life. The field experiment will be repeated on the same sites for three years. Progresses and accomplishments by objectives: The project was jeopardized by Covid-19 pandemic in 2020-2021 season, delaying some of our work and analyses. During the 2021-2022, we were able to resume all the planned activities as detailed in the proposal and managed to catch up the delays. We followed the same experimental design as the first year at SC and GA. After terminating the tomato in August 2021, we planted cucumbers in both SC and GA sites. Cucumbers were harvested in November at SC but were not able to reach maturity at GA. It is likely that local climate was not favorable for two vegetable seasons in the summer. Soil samples were collected prior to planting cover crops and analyzed in the soil lab at Pee Dee Research and Education Center. Cover crops were planting in mid-November 2021 at SC and GA, and terminated in April, followed by sweet corn planting in late April. The following describes research activities and accomplishments by objectives: Obj. 1: Evaluate how diversified organic inputs interact with tillage affecting soil microbial diversity and the functional groups associated with soil organic carbon (SOC), nitrogen (N), and phosphorus (P) cycling We diversified the organic inputs by planting different cover crops with varied biomass production potentials, which was further augmented by manure application in the winter. The preliminary data suggested the diversifying framework worked very well for consecutive two years. Diversified organic materials, as well as varied nutrient sources, were introduced as proposed. We are trying to estimate (by modeling) how much of cover crop biomass and C/N inputs can be generated per the local climate and planting time and rates. Preliminary data suggested that the production at both GA and SC were relatively low (\~4,000 kg ha-1) when compared to other regions. We were able to extract DNA from 2020 and 2021 soil samples collected from both SC and GA sties. Preliminary data suggested one season of cover cropping did not change the abundance of ammonia oxidation bacteria (AOB) and archaea (AOA), which were not affected by manure application and tillage. DNA samples will be sent for sequencing. More data is being analyzed. Obj. 2: Quantify the interactive impacts of diversified organic inputs and tillage on (a) C, N, and P biogeochemical processes and (b) short-term changes of soil health We have completed all the planned soils analyses collected from both sites (four sample events from 10/2020 to 5/2022) and are analyzing the data to understand short-term changes of soil carbon, nitrogen, and phosphorus in the context of pool size, distribution, transformation. The preliminary results suggested that varied organic inputs created by cover cropping and fertilization changed soil pH, nutrient availability, microbial respiration, and enzyme activities. These effects varied by the sources of the organic inputs. No significant changes in potential mineralization of organic N and labile organic C were observed, regardless of cover crop species, tillage types and fertilization schemes. Obj. 3: Evaluate how diversified management influences nutritional quality and yields of the vegetables For the first season (2020), we did not observe significant impacts of cover cropping and fertilization on the marketable yield of the tomatoes, but did find that conservation tillage (i.e., reduced tillage) reduced tomato yields in both sites, especially at SC, where low plant height and vegetation were found, likely resulted from the soil hard-pan impeding plant root growth. For the cucumber at the SC site, higher yields were found in plots with conservation tillage than those with conventional tillage, while planting cereal rye reduced the yields when compared to planting hairy vetch ,the mixture of hairy vetch and cereal rye, and no cover crop control. Obj. 4: Provide a transdisciplinary pedagogical framework that delivers enhanced educational opportunities for undergraduate/graduate students One MS and one PhD students were hired to work on this project. Both have their research proposal approved by their advisory committees. The MS student is writing his thesis on changes in soil health indicators and expected to graduate in December 2022. The PhD student will have his comprehensive exam in November 2022, who is trained on soil microbial community composition and functional groups associaed with nitrogen cycling. Both will present their research in the 2022 Tri-Societies Annual Meeting. Obj. 5: Disseminate research-based knowledge to promote the adoptions of diversifying management practices Due to the Covid-19 pandemic, the Pee Dee Research and Education Center canceled in person field day for two consecutive years (2020-2021). However, an extension handout was created by the station, which was distributed to local farmers and available online for free download. The handout includes descriptions for this specific project and some preliminary results. A webinar was also organized and presented on January 26, 2022 to provide research updates from this project. In addition, this research project was advertised to farmers, stake holders, the general publics, and academic communities through the extension outlets of both Clemson University and Rodale Institute. **Publications**

PROGRESS

2020/09 TO 2021/08 Target Audience:Research products/outcomes was directed to graduate and undergraduate students, extension specialists, organic farmers, and the general public. Results will be delivered to the academic communities through publications in peer-review journals and presentations in professional conferences. Research data may be stored in public data repository for free access. We will leverage the strength of Clemson University as a land grant university to disseminate research-based knowledge to farmers, stakeholders, and the general public by using the university\'s extension network. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Two graduate students were hired to work on this project. Advisory committees were identified to mentor the two graduate students. They were trained and supervised throughout their research. How have the results been disseminated to communities of interest? Due to the Covid-19 pandemic, our extension activities were limited. This research project was presented to and discussed with local farmers on a field day at GA. The research was advertised to farmers, the general public, extension agents, and academic communities through extension outlets of the Clemson University and Rodale Institute. A field day at the Pee Dee Research and Education Center was scheduled on 9 September 2021, in which we will disseminate the results from this work. What do you plan to do during the next reporting period to accomplish the goals? We have been greatly affected by the Covid-19 pandemic. However, we were able to manage the field while collecting soil and plant samples as planned in both SC and GA sites in the past year. No major changes are expected. We will continue to analyze the first-year data and follow the procedures detailed in the granted proposal for the next reporting period. Major activities are described by objectives as follows. Objective 1: we will continue the molecular approaches on microbial communities, including PCR, DNA sequencing, and metagenomic analyses, to determine the abundance of specific functional groups and the composition and metabolic potentials of microbial communities. Objective 2: we will use soil health assessment frameworks to evaluate short-term changes of soil health indicators in response to organic inputs and tillage. In addition to complete the analyses of soil carbon and nitrogen dynamics, we will conduct phosphorous fractionation analyses to investigate the distribution and stability of phosphorus introduced by manure application. Objective 3: The tomatoes in the fields are fruiting. We will prepare to harvest the tomatoes, estimate the yield and nutritional quality of the tomatoes, and compare nutrient use-efficiencies of the tomatoes under different management treatments. We have selected cucumber as the crop after tomato. The seeds were secured and will be planted directly to the field. Objective 4: The graduate students will have their respective committee meetings to discuss their research and education plans, while reporting their progresses and issues. In addition, the students will analyze their data, prepare slides, and present their research results to their host department. Both students are expected to spend some time in Co-PIs\' lab to get some training on laboratory and analytical skills. Objective 5: We will complete analyzing the first-year data from both field sites and prepare slides for presentations in field days, workshops, and academic conferences. Extension press publications may also be expected.

IMPACT

2020/09 TO 2021/08 What was accomplished under these goals? Issues being addressed: Increasing demands for organic vegetable has created high-value opportunities for conventional producers to transition to organic in southeastern states of USA, where the organic production acreages lags nations\' leading states. However, growers in the region are facing unique challenges in soils, which typically has low soil organic carbon, meager soil fertility, and poor soil structure. Increasing organic inputs (e.g. manure, compost, and cover crop), along with conservation tillage, is widely considered one of the best management strategies to address such soil health issues; yet the diverse available organic sources and their distinguished physiochemical properties, in combination with various management practices across spatial and temporary scales, may make desired economic and environmental outcomes less predictable. What we did and potential impacts: In this specific project, we tried to address whether this diversity in organic inputs can be managed to improve underground biodiversity and the soil processes underpinning soil health and the productivity of organic vegetables in southeastern soils, and whether tillage affects the outcomes. Field experiments were carried out simultaneously at Pee Dee Research and Education Center of Clemson University and Southeast Organic Center of Rodale Institute. Organic inputs were diversified by planting different cover crops and their mixtures, along with manure application. Through field and laboratory studies, we investigated the interactive effects of diversifying organic inputs and tillage on soil microbial community composition, soil carbon dynamics, nutrient cycling, soil health, and organic yields. The goal is to advance our knowledge and understanding of how management practices affect soil physio-biogeochemical processes that are important to the productivity, profitability, and sustainability of organic vegetables, providing research-based information to regional producers to improve ecosystem services and environmental stewardship of their farms, and their quality of life. Progresses and accomplishments by objectives: We conducted the field experiments in two certified organic fields at SC and GA simultaneously. The experiments have treatments of cover crop (cereal rye, hairy vetch, their mixtures, and no cover crop control) and manure application (with vs. without) randomly imbedded in the tillage treatment (conventional vs. conservation). Each treatment and their combinations were repeated four times in the fields, resulting in 64 plots in total on both sites. Cover crops were planted in November 2020 and terminated in April 2021. Chicken litter was applied in January 2021. Amelia tomatoes were transplanted in April and May 2021 at SC and GA sites, respectively. Soil samples were collected at the beginning of the experiments and prior to the termination of cover crops and analyzed in the soil lab at the Pee Dee Research and Education Center. The following describes research activates and accomplishments by objectives: Obj. 1: Evaluate how diversified organic inputs interact with tillage affecting soil microbial diversity and the functional groups associated with soil organic carbon (SOC), nitrogen (N), and phosphorus (P) cycling We diversified the organic inputs by planting different cover crops with varied biomass production potentials, which was further augmented by manure application in the winter. The preliminary data suggested the diversifying framework worked very well. Diversified organic materials, as well as varied nutrient sources, were introduced as proposed. We are trying to estimate (by modeling) how much of cover crop biomass can be generated per the local climate and planting time and rates. We were able to extract DNA from soil samples collected from both SC and GA sties. We are conducting real time quantitative PCR and conventional PCR (products will be sent out for sequencing) to estimate the abundance of specific functional groups, community composition. Obj. 2: Quantify the interactive impacts of diversified organic inputs and tillage on (a) C, N, and P biogeochemical processes and (b) short-term changes of soil health We have completed the analyses of all the soils sample collected from both field sites and are analyzing the data to understand short-term changes of soil carbon, nitrogen, and phosphorus in the context of pool size, distribution, transformation. A range of soil health indicators were selected and analyzed. We are analyzing the data to identify the short-term treatment effects. The preliminary results suggested that organic inputs changed soil pH, nutrient availability, and microbial activities, but these effects varied by the sources of the organic inputs. Obj. 3: Evaluate how diversified management influences nutritional quality and yields of the vegetables After terminating cover crops, tomatoes was trans-planted from the greenhouse on 15 April, 2021. The tomato was managed as proposed, including staking, irrigation, and the applications of organic pesticide, fungicide, and bactericide. The tomatoes are still growing. The yield and nutritional analyses will be estimated after harvest. Obj. 4: Provide a transdisciplinary pedagogical framework that delivers enhanced educational opportunities for undergraduate/graduate students Two graduate students were hired to work on this project, both of which are co-advised by PI and one of the Co-PIs. An advisory committee with professionals of varied disciplines was organized for each of the students, assuring their successful training. Obj. 5: Disseminate research-based knowledge to promote the adoptions of diversifying management practices Our research and extension activities were greatly affected by the Covid-19 pandemic, as a result of modified operation of Clemson University, travel ban, and longer time to secure lab and field supplies. We are still analyzing some of the first-year data. However, this project was presented on the field day of the Southeast Organic Center Farmer Gathering (11/17/2020, Rodale Institute). In addition, this research project was advertised to farmers, stake holders, the general public, and academic communities through the extension outlets of both Clemson University and Rodale Institute.

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Designing Farmer\`s Goal-oriented Organic Grain Rotations to Optimize Agronomic, Economic and Ecological Outcomes in Tennessee

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Performing Institution	UNIVERSITY OF TENNESSEE, 2621 MORGAN CIR, KNOXVILLE, TENNESSEE 37996-4540

NON-TECHNICAL SUMMARY

Tennessee farmers who have been in the forefront for promoting no-till management requires both philosophical and research-based guidance to transition to organic farming in which tillage is not currently completely avoidable. Consequently, the state lags far behind in organic grain production despite the fact that conventionally grown grains (corn, soybean, wheat) contribute to 33% of Tennessee\'s gross agricultural income. Excitingly, many conventional producers are interested in shifting to organic mainly due to rapidly increasing demand for organic produce. Through extensive interactions with producers and other stakeholders in Tennessee, the project team has identified the key challenges that prevent producers from transitioning to organic, and proposed this first integrated research, extension and education organic grain project to tackle those challenges. The overarching goal is to evaluate four organic grain crop rotations on certified organic land at two locations of Tennessee on agroecological (yield, weed control, nutrient cycling, soil health, and greenhouse gas emission) responses, pest and disease management, and profitability. The four unique rotations were designed by considering different priorities of farmers, which include (i) maximum production, (ii) maximum production with moderate tillage reduction, (iii) reduced tillage for enhancing sustainability, and (iv) cover-crop based low-input system avoiding reliance on external nutrient sources. The research outcome will be disseminated to stakeholders through well-developed extension and education programs. By providing critical information to Tennessee producers on regionally suitable organic grain management strategies to achieve profitability while minimizing ecological trade-offs, this project will contribute to enhancing sustainability of agroecosystems.

OBJECTIVES

The major goal of this project is to sustainably increase organic grain production in Tennessee to harness better profit while meeting national demand, reduced tillage organic production with sustainability as the prime focus, and low-input ecologically based grain production with closed nutrient cycling that does not rely on external inputs. The specific objectives of this project are developed based on the goals defined by local producers and other stakeholders. We will conduct organic soybean-wheat-corn rotational field experiments at two distinctly different locations in Tennessee for three years with the following specific objectives: Objective 1: Quantitatively compare the effects of four organic grain production systems on crop productivity, weed suppression, soil nutrient cycling, soil health, and greenhouse gas mitigation potential. Objective 2: Identify common pests and diseases issues in organic corn, soybean and wheat systems, and determine which management scenarios effectively control them. Objective 3: Conduct a comparative economic analysis to identify the most profitable organic cropping rotationObjective 4: Integrate the knowledge generated into Extension and education programs that aim to improve producers\' awareness and adoption of organic grain production

APPROACH

We will conduct a 3-year field experiments in certified organic lands at two geographically distinct locations of Tennessee, which have different soil types. Site 1 (UT site) is at the Organic Crops Unit, which is part of East Tennessee Research and Education Center of the University of Tennessee in Knoxville, TN, and Site 2 (MTSU site) is at the Middle Tennessee State University\'s Experiential Learning and Research Center in Lascassas, TN. We will evaluate four organic grain cropping rotations as treatments to meet four unique goals of the producers: (i) maximizing grain production as the primary goal, (ii) maximizing grain production while reducing tillage events, reducing tillage as the primary goal, and reducing tillage as well as excluding external nutrient inputs. We will conduct a detailed agronomic and ecological data collection throughout the length of the project. Specifically, grain (corn, soybean and wheat) yield, biomass (both cash crop and cover crop) ground coverage and weed biomass data will be collected. Soil samples will be collected three times per year to analyze for parameters pertinent to carbon and nutrient cycling including active and total soil organic carbon, plant available nutrients, aggregate stability, greenhouse gas emissions and residue decomposition. In addition, pests and disease scouting will be conducted in year 1 and 2, and appropriate corrective measures will be employed in year 3. A detailed economic analysis will also be conducted in year 3 to determine the profit maximizing organic grain cropping system, and to compare the profit with the non-organic grain cropping system. Very extensive Extension and education activities will be carried out to disseminate the research experiences and knowledge gained from the project to stakeholders. Progress 09/01/20 to 08/31/24 Outputs Target Audience:This project served a range of stakeholders in Tennessee and surrounding regions, interested in and passionate about organic farming and products. The primary audience included organic grain farmers cultivating corn, soybean, and wheat who applied the project\'s guidance on cover crop management, crop rotations, reduced tillage practices, and efficient planting schedules. These improvements were tailored to bolster farm resilience, enhance soil health, improve weed suppression, and mitigate GHG emissions. Farmers thus learned practical strategies to increase productivity, reduce input costs, and foster long-term sustainability. This project also served academic partners and students, including researchers at UTK and MTSU, who integrated details of this project and the findings into their undergraduate and graduate curricula. Graduate and undergraduate students received hands-on training on field and laboratory components of the research, strengthening their competencies in sustainable agriculture research methods, data analysis, and critical thinking. These skills are critical for their career preparation as scientists, extension agents, or industry professionals. High-school students and non-formal educators engaged through the Digital Agriculture Summer Camp and Digital Agriculture Academy were introduced to scientific concepts, digital tools, and fundamental principles of organic farming, thereby strengthening the pipeline of future agricultural innovators. The project\'s relevance extended to industry representatives such as seed producers and equipment manufacturers seeking insights to align product lines with evolving producer needs and policymakers who require evidence-based data on carbon sequestration, soil improvements, and GHG mitigation. Outreach materials and conversations with decision-makers ensured that research outcomes encouraged the adoption of organic practices. By reaching extension professionals, community groups, and the broader public through demonstration hubs at UTK and MTSU, YouTube videos, factsheets, and on-farm workshops, the project cultivated a more informed community supportive of regenerative and organic agriculture. Changes/Problems:After the approval of the entire project team, the following minor changes were implemented: The roller crimper proved ineffective in terminating the triticale and hairy vetch cover crop mix before soybean, leading to uneven soybean stands. Additionally, the heavy mulch layer generated by profuse cover crop growth hindered standard planter performance, resulting in poor seed germination. To address these challenges, hairy vetch was replaced with radish in the cover crop mix, and row scrapers were attached to planters. These adjustments significantly improved soil-seed contact and soybean germination. Relay planting of red clover and timothy in Treatment 4 faced significant challenges throughout the project, with multiple attempts yielding limited success. Efforts to establish these cover crops included sowing at various time points and adjusting row spacing. While Timothy failed to germinate under all tested conditions, red clover showed successful establishment when planted during periods of adequate moisture and warm temperatures. Due to severe soil compaction in heavy clay soils, sampling depth was reduced from three increments (0-5 cm, 5-15 cm, and 15-30 cm) to two (0-5 cm and 5-15 cm). Unpredictable weather conditions and the extended growing season posed challenges in meeting yield targets. To mitigate this, low-maturity soybean varieties were adopted to enable earlier harvesting in Year 3 and improve land management timing. Soybean establishment was particularly challenging in the first two years, resulting in negligible yields. A no-cost extension allowed the project to collect and analyze two years of publishable data on full-season soybean yields. What opportunities for training and professional development has the project provided?Over the course of three years, the project provided diverse training and professional development opportunities to students, fostering technical expertise, leadership, and career readiness in sustainable agriculture. Three Ph.D. students were trained in agronomic attributes, soil health, pest and disease management, and GHG emissions. Two PhD students focusing on the project\'s agronomy, soil science, and GHG components have recently graduated, while the third Ph.D. student working on pest and disease components is on track to graduate in Summer 2025. In addition to the project funds, we leveraged funds from the University to engage three Ph.D. students in the project. Two students received the UTK \"Student/Faculty Research Award\" (SFRA) for pursuing additional research objectives by leveraging this project, enabling them to acquire advanced technical and research skills. The third student completed two pest and disease diagnostic courses and attended scouting school for grain crop pests, gaining essential knowledge and skills for pest identification and monitoring in the field. One student received southern SARE grant to study organic double-crop soybean productivity. By writing this grant, this student also gained grant-writing expertise. This student also participated in policy-related discussions as a student representative of the Science and Policy Committee of the Soil and Water Conservation Society. All three students participated in professional society meetings and field day demonstrations, gaining practical experience in stakeholder engagement and formulating organic grain crop recommendations. Over 10 undergraduate students received hands-on training in soil and plant sampling, GHG flux measurements, laboratory analyses, and data analysis, working closely with project faculty at UTK. At MTSU, Dr. Cui\'s integration of project findings into coursework, along with field demonstrations and training sessions for undergraduates, high-school students, and non-formal educators, enhanced their understanding of sustainable organic farming practices. Interns with Dr. Smith developed economic analytical skills, creating enterprise budgets for organic crops, analyzing variable and fixed costs, and evaluating production scenarios. These activities enhanced computational, critical thinking, and teamwork skills, preparing them for future roles in agricultural research and management. Annual meetings, field days, and producer consultations not only provided practical experience to graduate students but also strengthened their communication and decision-making abilities. Additionally, graduate students gained skills in preparing materials for field days, such as fact sheets and other extension resources, ensuring that complex research findings were effectively communicated to producers and stakeholders. Students at MTSU, trained by Dr. Cui, further developed real-world skills in marketing strategies, equipping them for future roles in entrepreneurship. How have the results been disseminated to communities of interest?The project employed multiple dissemination pathways, ensuring that findings reached target communities. Direct producer interactions through phone calls, emails, and in-person meetings addressed specific inquiries on transitioning to organic systems, local markets, sourcing inputs, and production contracts. Major regional conferences (Pick TN, Middle and West Tennessee Grain Conferences, Kentucky/Tennessee Grain Day) and professional society meetings (ASA-CSSA-SSSA, Soil and Water Conservation Society) showcased research findings to a wide range of agricultural professionals. Presentations detailed the comparative economic performance of different organic grain cropping systems, informing producers about the profitability and sustainability implications of their choices. On-site field visits allowed farmers and extension personnel to observe management practices firsthand. Direct consultations with local farms (e.g., Sequatchie Cove Farm and Caney Fork Farm) and engagements with NRCS agents ensured that our research addressed stakeholders\' questions. Digital media, including a YouTube video series on bioformulation, pest management, and cover crop techniques found in the following link https://www.youtube.com/playlist?list=PLcl0oMHFeTCSciydeRVMFAdzbrzWhB2qp, reached an online audience of over 7,000 viewers. Drafted fact sheets, currently under review for UT Extension publication, offer concise guidance on pest and weed control, soil health indicators, and organic transitioning strategies. Events like the Digital Agriculture Summer Camp and Digital Agriculture Academy engaged high-school students and non-formal educators, introducing scientific experimentation and organic grain production concepts. As part of the project\'s outreach efforts, several decision support tools were developed to assist producers in optimizing their production practices and navigating the transition to organic systems. For example, organic corn, soybean, and wheat budgets were created using data from the field experiment and industry resources. These budgets include customizable templates for input costs, fixed expenses, and labor, as well as breakeven sensitivity analyses for yield and price under specified cost structures. The budgets will soon be publicly accessible on the University of Tennessee Extension Budget page: https://arec.tennessee.edu/extension/budgets/. Through these combined efforts, the project not only advanced scientific understanding but also promoted broad adoption of best practices and informed decision-making among producers and other 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? Objective 1:Quantitatively compare the effects of four organic grain production systems on crop productivity, weed suppression, soil nutrient cycling, soil health, and greenhouse gas mitigation potential The third year of this study achieved significant progress in balancing productivity, sustainability, and practical strategies for organic grain cropping systems: Highly Tilled System (HTS), Moderately Tilled System (MTS), Least Tilled System (LTS), and Low Input System (LIS). Earlier sowing of cover crops facilitated better establishment and higher biomass in HTS and MTS (7-12 Mg ha-1), improving weed suppression, while LIS had the lowest biomass (0-6 Mg ha-1) and highest weed pressure. Fertilized systems (HTS, MTS, LTS) maintained satisfactory yields, with third-year averages of 4.66 Mg ha-1 for corn, 2.47 Mg ha-1 for full-season soybean, 4.06 Mg ha-1 for winter wheat, and 1.5 Mg ha-1 for double-crop soybean, highlighting the yield stability of reduced tillage when supported by strategic management. Early-maturity and double-crop soybean varieties mitigated weather risks, ensuring predictable harvests. Higher biomass directly improved weed suppression, while LTS showed moderate yields but slightly higher weed pressure due to lower biomass, and LIS lagged behind in both yield and weed control. Reduced tillage systems (MTS, LTS) matched HTS productivity while enhancing soil organic carbon (SOC) storage in the surface layer (0-5 cm), with organic matter increasing from 2.8% to 3.9% over three years across the treatments. These systems improved active carbon (C) pools (permanganate oxidizable C and water-extractable organic C), nitrogen cycling, and aggregate stability in the surface layer, without significant subsoil effects. The soil health assessment revealed significant improvements in physical, chemical, and biological metrics, particularly in the upper soil layer (0-5 cm). Reduced tillage systems, such as MTS and LTS, exhibited higher weighted soil health index values compared to HTS and LIS, highlighting their role in promoting overall soil health. In terms of greenhouse gas mitigation, N2O emissions were highest in systems with higher tillage and poultry litter (PL) application, particularly during the corn phase (13 kg N2O-N ha-1), whereas reduced-tillage systems like MTS and LTS exhibited lower emissions (20 kg N2O-N ha-1). LIS had the lowest emissions (6 kg N2O-N ha-1) due to the exclusion of PL. Across all systems, organic rotations acted as a net carbon sink, with a mean global warming potential of -7.6 Mg CO2-eq ha-1 yr-1, emphasizing the capacity of organic systems to offset emissions through increased soil carbon sequestration. Strategic management, such as decoupling PL application from cover crop termination and reducing tillage intensity, proved effective in mitigating emissions while maintaining productivity. The study findings indicated that MTS and LTS can sustain competitive yields while improving soil health and environmental quality. Higher tillage system maintained high productivity but poses long-term risks to soil quality and contributes to higher greenhouse gas emissions, while LIS, with limited inputs and management intensity, struggled to match the productivity and ecological benefits of other systems. Objective 2:Identify common pests and diseases issues in organic corn, soybean and wheat systems, and determine which management scenarios effectively control them Corn earworm (Helicoverpa zea) emerged as a primary pest in corn and was managed effectively through the deployment of sex pheromone traps containing (Z)-11-hexadecenal and (Z)-9-hexadecenal. Increasing trap numbers reduced populations, though further research is needed to optimize cost-effectiveness. Tillage practices did not affect corn earworm populations, making trap-based management applicable across diverse production systems. In soybeans, pest dynamics were influenced by tillage intensity. Reduced and no-till plots, with higher weed cover, supported larger populations of three-cornered alfalfa hopper (Spissistilus festinus), while stink bugs (Acrosternum hilare and Euschistus spp.) were more prevalent in tilled plots where soybean maturity and pod production provided a food source. These results emphasized the need for integrated tillage and weed management strategies to balance pest control and crop development. Disease pressure was minimal, with isolated cases of common rust, smut, and purple leaf sheath in corn and limited Fusarium wilt in soybeans. Disease incidence appeared inversely related to weed diversity, possibly due to altered microclimatic conditions, such as reduced humidity, that hinder pathogen proliferation, suggesting a potential disease-suppressive effect of diverse field conditions. Objective 3:Conduct a comparative economic analysis to identify the most profitable organic cropping rotation The economic performance of four distinct organic cropping systems was assessed through partial net return analysis, focusing on revenue and variable costs associated with yield, poultry litter application, cover crop mix, tillage system, and double cropping. The analysis excluded fixed costs and elements unaffected by production practices to isolate the economic impact of management decisions. The results revealed that partial net returns were primarily driven by yield differences across treatments, with HTS generating the highest returns at \$4,348.24, followed by MTS at \$3,496.26, LIS at \$2,735.17, and LTS at \$2,326.36. HTS and MTS benefited from higher yields and supported double cropping, which contributed to their superior economic performance despite incurring higher costs for tillage, cover crop mix, and poultry litter application. In contrast, LIS minimized input costs by eliminating poultry litter and using a less intensive cover crop mix but achieved lower returns due to reduced yield. Similarly, LTS, which prioritized ecosystem enrichment, incurred higher cover crop costs without significant yield gains to offset expenses. Objective 4:Integrate the knowledge generated into Extension and education programs that aim to improve producers\' awareness and adoption of organic grain production By translating complex, data-driven results into practical, actionable information, the project bridged the gap between research and real-world application. At UTK, faculty incorporated results into graduate and undergraduate student mentoring on soil health, greenhouse gas mitigation, agronomy, and pest management, ensuring that future agricultural professionals gain familiarity with sustainable practices. At MTSU, two courses integrated findings using Team-Based and Problem-Based Learning techniques, where Dr. Cui addressed organic grain production challenges. Multiple extension-oriented strategies including YouTube videos and participation in field days were employed to reach farmers, advisors, and community members. Presentations at conferences and regional meetings engaged participants in discussions about weed management tactics, planting and harvesting issues, pest control strategies, and profitability assessments. Field days allowed producers to see firsthand how optimized rotations, reduced tillage intensity, and strategic cover crop management could enhance productivity and soil health. Digital outreach, including instructional YouTube videos, fact sheets, and targeted social media communication, further amplified the project\'s reach, informing a broader audience about the opportunities and challenges in organic grain systems. These integrated extension and education efforts not only increased awareness and knowledge but also equipped stakeholders with the confidence and practical know-how to implement new strategies on their farms. Publications Type: Other Status: Published Year Published: 2023 Citation: Smith, S.A. and Bowling, B. 2023. Organic and conventional corn production profitability tool. Tennessee Corn Board, January 17, Mt. Juliet, TN (Oral). Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Chhetri, A., Jagadamma, S., and Saha, D. 2023. The impact of organic grain production systems on soil-derived greenhouse gas emissions. ASA-CSSA-SSSA International Annual Meeting, Oct. 31-Nov. 1, Saint Louis, MO. (Oral). Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Chhetri, A., Jagadamma, S., DeBruyn, J., and Saha, D. 2023. Microbial pathways controlling hot moments of nitrous oxide emissions from organic cropping systems. ASA-CSSA-SSSA International Annual Meeting, Oct. 31-Nov. 1, Saint Louis, MO. (Poster). Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Smith, S.A., Saha, D., Ownley, B., Cui, S., and Jagadamma, S. 2024. Designing farmers goal-oriented organic grain rotations to optimize agronomic, economic and ecological outcomes in Tennessee. Middle Tennessee Grain Conference, January 30, Tullahoma, TN (Oral). Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Neelipally, R. T., and Jagadamma S. 2024. Soil health in organic grain systems. Pick TN Conference, February 15-17, Franklin, TN (Oral). Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Smith, S.A., Saha, D., Ownley, B., Cui, S., and Jagadamma, S. 2024. Designing farmers goal-oriented organic grain rotations to optimize agronomic, economic and ecological outcomes in Tennessee. West Tennessee Grain Conference, February 1, Dyersburg, TN (Oral). Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Smith, S.A., Saha, D., Ownley, B., Cui, S., and Jagadamma, S. 2024. Designing farmers goal-oriented organic grain rotations to optimize agronomic, economic and ecological outcomes in Tennessee. Kentucky/Tennessee Grain Day, February 2, Russellville, KY (Oral). Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Neelipally, R. T., Saha, D., Hawkins, S. A., Cui, S., and Jagadamma, S. 2024. Impact of conservation tillage strategies on soil health in organic grain cropping systems. 79th SWCS International Annual Conference, July 21-27, Myrtle Beach, SC (Oral). Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Neelipally, R. T., Saha, D., and Jagadamma, S. 2024. Defining boundaries and conceptual frameworks for ecologically focused agricultural systems. Journal of Soil and Water Conservation, 79(4), 61A-65A. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Chhetri, A., Jagadamma, S., and Saha, D. 2024. Soil nitrous oxide (N_2O) emissions and greenhouse gas budget from organic cropping systems. ASA-CSSA-SSSA International Annual Meeting, Nov. 10-Nov. 14, San Antonio, TX (Oral). Type: Theses/Dissertations Status: Accepted Year Published: 2024 Citation: Chhetri, A. 2024. Nitrous oxide emissions from transitioning organic production systems: quantification and driving factors (Dissertation). University of Tennessee, PhD Dissertation. Type: Other Journal Articles Status: Under Review Year Published: 2024 Citation: Neelipally, R. T., Saha, D., Cui, S., and Jagadamma, S. 2024. Agronomic responses from diverse tillage and cover crop integrated organic grain transitioning systems, Agronomy Journal (Under Review). Type: Other Status: Other Year Published: 2024 Citation: Cui S. 2024. Scientific experiment concepts and benefits of organic grain crop production. MTSU Digital Agriculture Summer Camp, May 29-Jun.14, Murfreesboro, TN (Oral). Type: Other Status: Under Review Year Published: 2024 Citation: Ouma, W., Grant, J., Jagadamma, S., Neelipally, R., Shoemaker, D., and Ownley, B. 2024. Southwestern corn borer in organic corn. UT Extension Publication (Under Review). Type: Other Status: Under Review Year Published: 2024 Citation: Ouma, W., Grant, J., Jagadamma, S., Neelipally, R., Shoemaker, D., and Ownley, B. 2024. Corn earworm in organic corn. UT Extension Publication (Under Review). Type: Other Status: Under Review Year Published: 2024 Citation: Ouma, W., Grant, J., Jagadamma, S., Neelipally, R., Shoemaker, D., and Ownley, B. 2024. Japanese beetle in organic soybean. UT Extension Publication (Under Review). Type: Other Status: Under Review Year Published: 2024 Citation: Ouma, W., Grant, J., Jagadamma, S., Neelipally, R., Shoemaker, D., and Ownley, B. 2024. Stink bugs in organic soybean. UT Extension Publication (Under Review). Type: Other Status: Under Review Year Published: 2024 Citation: Ouma, W., Grant, J., Jagadamma, S., Neelipally, R., Shoemaker, D., and Ownley, B. 2024. Common weeds in organic corn and soybean systems in Tennessee. UT Extension Publication (Under Review). Type: Theses/Dissertations Status: Under Review Year Published: 2025 Citation: Ouma, W. 2025. Pest and Disease Management in Organic Grain Systems: Identification, Prevention, and Corrective Strategies for Organic Grain Rotations in Tennessee Farms (One chapter of the dissertation) Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Neelipally, R. T., Saha, D., Hawkins, S. A., Cui, S., and Jagadamma, S. 2024. Evaluating soil health and crop productivity under different tillage regimes in organic grain cropping systems. ASA, CSSA, SSSA International Annual Meeting, Nov. 10-Nov. 14, San Antonio, TX (Oral). Type: Theses/Dissertations Status: Accepted Year Published: 2024 Citation: Neelipally, R.T. 2024. Integrating conservation strategies in organic grain cropping systems for agronomic and soil health outcomes. University of Tennessee, PhD Dissertation. Progress 09/01/22 to 08/31/23 Outputs Target Audience:The primary target audience includes organic grain farmers engaged in cultivating soybeans, wheat, and corn. These farmers, along with extension agents and other agricultural professionals gained vital insights into optimal practices for crop rotations, cover crop mixtures, comprehensive crop management schedules, and tillage-reduction options. Tennessee Corn Promotion Board and Tennessee Craft Distillers and Brewers Association were also addressed on the organic grain production economics and risks to evaluate the viability and sustainability of transitioning from conventional to organic farming. Students at the University of Tennessee-Knoxville and Middle Tennessee State University have also benefited, as information on grain production, greenhouse gas mitigation, and pest and disease control has been integrated into teaching programs by project participants. The project also facilitated hands-on research training for undergraduate and graduate students within the specialized labs of Jagadamma, Saha, and Ownley at UTK, and Cui at MTSU, integrating these experiences with real-world agricultural practices. Changes/Problems:Some management changes were implemented based on the lessons learned from previous years including seed drilling depths, weed control measures, variety selection, planting and harvesting dates, etc. All changes were communicated with the project team in advance of implementation and these changes improved the agronomic performance of the system. The project received a one-year no-cost extension from 09-01-2023 to 08-31-2024. During this period, one more year of field data will be collected, and the peer-reviewed and extension publications will be prepared. The PIs start-up funds and departmental support will cover the resources needed for this additional period. What opportunities for training and professional development has the project provided?Three doctoral candidates, one of whom is departmentally funded, are undergoing training in agronomy, soil health, and pest/disease management, as well as greenhouse gas emissions. Seven undergraduates received training in soil and plant sampling and analysis, as well as gas flux measurements. The Ph.D. student supervised by Dr. Saha secured a \$5,000 university seed grant for studying microbial control on nitrous oxide emissions. This student is trained in microbial DNA extraction, plasmid transformation, and qPCR analysis. Another Ph.D. student, supervised by Dr. Jagadamma, received funding (\$16,000) from southern SARE for research on wheat-soybean double crop productivity in the southeastern U.S. At the Middle Tennessee State University, over 30 undergraduate students participated in classes featuring field demonstrations in transitional corn/soybean production. Dr. Cui trained an undergraduate in soil/plant sampling and lab analysis. How have the results been disseminated to communities of interest?Project director Jagadamma has been in constant communication with local organic farmers and Natural Resources Conservation Services (NRCS) field officers about the project. The team is looking forward to presenting our findings at the 2023 field day events at the field sites. Our 2-yr data is also being disseminated across the farming and academic communities through poster and oral presentations indicated in the products section. An inquiry was received from an undergraduate student at Vanderbilt University pertaining to research in organic grain rotation systems. The student is engaged in a summer project to provide agricultural training in Bolivia, with a focus on workshops concerning sustainable agriculture and organic farming innovations. Specific interest was noted in organic rotation systems and wheat cultivation. A comprehensive response was provided, detailing relevant innovations and insights that align with the student\'s project objectives, thereby contributing to the broader initiative of disseminating sustainable agricultural practices. At Middle Tennessee State University, field day events disseminated research findings to various educational demographics in middle Tennessee. Dr. Song collaborated with the university\'s Deeper Learning Institute to instruct high school teachers from multiple districts on organic agriculture production practices. What do you plan to do during the next reporting period to accomplish the goals?The team plans to extend the field experiment by one year to offset the initial yield loss, thereby facilitating a three-year comprehensive analysis across all objectives. Economic data analysis results will continue to be utilized in stakeholder discussions. Knowledge dissemination is planned through the publication of fact sheets and research articles related toagronomic, ecological, and economic objectives. Engagement will persist with the growing organic farming community, conventional farmers transitioning to conservative practices, and the scientific community through field days in Tennessee and professional meetings. Two Ph.D. students are expected to graduate during this reporting period as well. Impacts What was accomplished under these goals? 1. Quantitatively compare the effects of four organic grain production systems on crop productivity, weed suppression, soil nutrient cycling, soil health, and greenhouse gas mitigation potential In the second year, a successful harvest of wheat (reported in 2022), corn, and double-cropped soybean was achieved. Within the T1 disk-tilled plot, full-season soybean planted with a standard planter yielded 1.88 Mg/ha, whereas other no-till plots remained unharvested due to weed interference. Employing a planter with row scrappers for double-crop soybean led to yields of 3.92 Mg/ha and 3.54 Mg/ha in T1 and T2 systems, respectively. Corn yield in T2 reached 6.64 Mg/ha, significantly exceeding the yields in other treatments (T1- 5.64, T3- 5.04, and T4- 5.48 Mg/ha). In the third year, several management adjustments were implemented, based on the lessons learned from the previous years, to further enhance the yield. During Fall 2022, cover crops were planted early to enable the establishment of legumes and brassica species prior to the onset of winter frost, leading to successful cover crop establishment across all treatments. The resultant cover crop biomass ranged between 4 and 11.5 Mg/ha, except for T4 corn where red clover and timothy grass mixture failed to establish. Additionally, early-maturity full-season and double-crop soybean varieties were employed to facilitate earlier harvesting in the current year. Weed infestation was assessed quantitatively using a quadrat during the harvest of wheat and cover crops, and qualitatively via the \"Canopeo\" mobile application at the vegetative stage in corn and soybeans. Data analysis indicated that the suppression of weeds by cover crop biomass positively influenced cash crop yield. Weed management was done by mechanical approaches such as inter-row cultivation and hand mowing at the early vegetative stage. Soil samples collected three times annually from 0-5 cm and 5-15 cm depths, revealed inconsistent soil organic carbon (SOC) concentrations within the year, but all treatments had significantly higher SOC compared to baseline. Similar trends were seen in labile carbon pools without significant differences among treatments. The percent change in potentially mineralizable nitrogen (PMN), measured after poultry litter application in corn, showed a linear relationship with the change in inorganic nitrogen in the field. PMN may thus serve as an indicator of nitrogen availability in organic systems. Gas samples were collected based on the management practices (e.g., tillage, planting, manure application) and the weather events (e.g., precipitation). Collected gas samples were analyzed for carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) using a gas chromatograph. Soil moisture and soil temperature data from 0-15 cm soil depths were recorded at each gas sampling event. Soil samples were collected bi-weekly to monthly interval for analysis of mineral nitrogen. In 2022, 51 gas sampling events were conducted, where N2O emissions were highest in the corn phase of rotation (average 12.13 kg N2O-N ha-1) followed by soybean (average 2.6 kg N2O-N ha-1), and wheat (average 1.6 kg N2O-N ha-1). Up to this reporting date, 34 sampling events have occurred in 2023, and data are now undergoing analysis. In 2022, an experiment was executed during the T2 corn phase to investigate N2O emission dynamics in response to cover crop growth and poultry litter application. The study will be replicated in the third year. Approximately 80% of the cover crop residue decomposed within a 15-week period, however, poultry litter exhibited no significant impact on this decomposition rate. N2O emissions were found to be markedly lower in treatments without poultry litter compared to those with the litter (3.5 vs. 26 kg N2O-N ha-1). Supported by a seed grant from the University, molecular analyses were conducted, including genomic DNA abundance related to nitrogen cycling and N2O isotopomer partitioning. These indicated denitrification as the predominant microbial pathway for N2O emissions. Data collection for these metrics continues for the 2023 growing season. 2. Identifying common pest and disease issues in organic corn, soybean and wheat systems, and determine which management scenarios effectively control them In the cash crop phases of our agricultural rotation, pest and disease surveillance is being conducted through systematic scouting and the deployment of pheromone traps. In the previous year, Corn Earworm was identified as a significant pest in the corn crop, a finding substantiated by pheromone trap data. To enhance pest control efficacy, the quantity of Corn Earworm traps has been doubled for 2023, along with the inclusion of traps for Southwestern Corn Borer, European Corn Borer, and Fall Armyworm. During the current growing season, incidences of Southern Corn Rust and Aspergillus Ear Rot have been observed in selected plots. Integrated management strategies, including the selection of resistant cultivars, weed control, and early harvest, are being employed to mitigate economic losses due to disease. 3. Conduct a comparative economic analysis to identify the most profitable organic cropping rotation An economic assessment was executed to ascertain the profitability of organic grain cultivation in the southeastern United States. Mean market prices per bushel stood at \$9.4 for corn, \$28.83 for soybean, and \$9.12 for wheat. Breakeven yields, based on variable costs, were determined as 84 bushels for corn, 17 bushels for soybean, and 39 bushels for wheat. The analytical framework employed involved the development of cost-return budget models, computation of breakeven prices and yields, and adjustments to the organic cost structure, informed by empirical evidence and consultations with existing organic grain producers. This methodology will be maintained to ensure an objective evaluation of the economic viability of four distinct organic cropping systems. 4. Integrate the knowledge generated into Extension and education programs that aim to improve producers\' awareness and adoption of organic grain production Ph.D. student under the supervision of Jagadamma disseminated visual content of field activities through platforms including Twitter, the lab website, and YouTube. Following a YouTube presentation, several farmers engaged to inquire further about the project. The findings were also shared at the extension and stakeholder-centric Tennessee Agricultural Production Association\'s annual meeting, Soil and Water Conservation Society\'s annual conference, Tennessee Corn Promotion Board annual meeting, and Tennessee Craft Distillers and Brewers Association meeting. Additionally, PIs of the project have integrated the project\'s outcomes into undergraduate curricula, broadening the educational reach of these insights. Economic data is disseminated through data-driven tools such as the Corn Profitability Decision Aid while addressing economic and risk factors in organic grain production at various meetings. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Chhetri A, Jagadamma S, and Saha D. 2022. Drivers and controls of nitrous oxide emissions during cover crop decomposition in organic crop rotation. ASA-CSSA-SSSA Annual Meeting, November 6-9, Baltimore, MD (poster). Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Neelipally RTKR., Saha D., Cui S., Hawkins S.A.,

and Jagadamma S. 2023. Reduced tillage in organic grain cultivation: implications on agronomic production and soil organic carbon accumulation. Tennessee Agricultural Producers Association Annual Meeting & Agronomic Workshop, July 18-20, Buchanan, TN (presentation). Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Neelipally RTKR., Saha D., Cui S., Hawkins S.A., and Jagadamma S. 2022. Designing organic grain rotation systems for agronomic and soil health benefits. ASA-CSSA-SSSA Annual Meeting, November 6-9, Baltimore, MD (poster). Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Neelipally RTKR., Wooliver R., Ownley B.H., and Jagadamma S. 2022. Cow manure-based bioformulations as a plausible approach to rejuvenate soil and enhance plant growth. ASA-CSSA-SSSA Annual Meeting, November 6-9, Baltimore, MD (poster and rapid oral presentation). Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Chhetri A, Jagadamma S, and Saha D. 2022. Soil nitrous oxide emissions from corn phase of organic grain production systems in Tennessee. ASA-CSSA-SSSA Annual Meeting, November 6-9, Baltimore, MD (poster). Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Neelipally RTKR., Saha D., Cui S., Hawkins S.A., and Jagadamma S. 2023. Whole systems approach to reducing tillage in organic farming: challenges and opportunities in the southeastern USA. 78th Society Conservation Society International Annual Conference, Des Moines, IA (presentation). Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Smith A. 2023. Organic Corn, Soybean, and Wheat Production Economics and Risk. Tennessee Corn, Soybean, and Wheat Producers Meeting, March 31- 86 participants (online presentation). Type: Other Status: Under Review Year Published: 2023 Citation: Smith A. 2023. UT Organic Crop Budgets Type: Other Status: Submitted Year Published: 2023 Citation: Smith A. 2023. Corn Profitability Comparison Tool. Department of Agricultural and Resource Economics, UT Institute of Agriculture (Decision-Aid tool). **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: The project directly addressed organic farmers in Tennessee who cultivate soybeans, wheat, and corn. Farmers seeking to enhance soil health and increase the farm's sustainability profited from the study's preliminary findings. Farmers and stakeholders also benefited from the project's insights on better crop rotations, cover crop (CC) mixtures, suitable planting times, and tillage-reduction options. Attending a workshop on this project at Middle Tennessee State University (MTSU), one of our study sites, 35 high school teachers learned knowledge that may be incorporated into their curriculum to teach farming operations and soil health to their students. Undergraduate and graduate students at University of Tennessee-Knoxville (UTK) and MTSU also received project-generated information on grain production, greenhouse gas mitigation, and pest and disease control in organic systems from courses taught by Drs. Ownley and Cui. At the experimental sites in UTK and MTSU, the farm crew and the PIs shared knowledge generated from the field experiment to stakeholders and public who visited the center. This project also provided research training opportunities to multiple undergraduate and graduate students in the labs of Jagadamma, Saha, and Ownley at UTK and Cui at MTSU. Changes/Problems: Hairy vetch and triticale mix before soybean was replaced with triticale and radish mix, to overcome challenges in terminating hairy vetch by rolling and crimping. A legume CC before soybean is also beneficial anyway. Seeding rate of hairy vetch in the CC mix was reduced to 50% and replaced with fast growing winter pea to avoid low ground coverage of the CC mix in fall. Seeding rate of soybean in the no-till plots was increased by 50% compared to 30% last year to have better establishment. However, the lack of row cleaners on no-till planter decreased the soil contact of the seeds and hindered the germination. Even after several sowings, relay planting of red clover and timothy in T4 wheat treatment has been unsuccessful for the past two years. This will be remedied during the following growing season by increasing wheat row spacing and simultaneously planting CCs. More specialized planter attachments will be made available for next year to ensure optimum planting and weed control to facilitate achieving better yields. Sampling depth increments has been reduced from three (0-5 cm, 5-15 cm, and 15-30 cm) to two (0-5 cm and 5-15 cm) at both sites due to severe soil compaction of heavy clay soils. What opportunities for training and professional development has the project provided?Three Ph.D. students (one departmental funded) have been receiving training in agronomic attributes, soil health, pest and disease management, and GHG emission. Five undergraduate students have been trained so far in soil and plant sampling and analysis, as well as GHG flux measurements. In years 2021 and 2022, a Ph.D. student supervised by Bonnie Ownley, who is working on diseases, pests, and weed scouting, completed two diagnostic trainings for plant pests and diseases. These trainings enhanced the student's skills necessary to identify pests, diseases, and weeds in the field, which is critical towards the completion of Objective 2 of the study. Ph.D. student supervised by Jagadamma was awarded a \"Student/Faculty Research Award\" (\$5,000) by the UTK Graduate School to develop and evaluate organic microbial bio-formulations from cow manure on plant growth and soil microbiomes. This study investigated the impacts of two natively prepared bio-formulations from organic sources on the growth characteristics of organic wheat, soybeans, and corn. To accomplish this project, the student was trained to extract and sequence microbial DNA through Next Gen Sequencing, analyze it in a bioinformatics lab, and then identify the microbial population that could be beneficial for the rejuvenation of soils. Finding of this side-study will complement the goals of our larger-study on organic grain production. At the MTSU site, a research associate working under Song Cui has gained a lot of training and practical knowledge about the production constraints of the organic systems. How have the results been disseminated to communities of interest? Project director Jagadamma has been in constant communication with local organic farmers and Natural Resources Conservation Services (NRCS) field officers about the project. Ph.D. student supervised by Jagadamma published multiple photos and short videos of field activities via social media such as Twitter, lab website, and YouTube. He was approached by multiple farmers to learn more about the project after watching a YouTube video. The team also presented the preliminary findings at the 2022 field day event at one of the field sites. The presentation was well-attended and generated a lot of enthusiasm among stakeholders. Our first-year data is also being disseminated across the farming and academic communities through the poster and oral presentations indicated in the products section. What do you plan to do during the next reporting period to accomplish the goals? The team intends to continue the triannual soil sampling, periodic gas sampling, and pest and disease scouting from field experiments along with collection and analysis of CCs and cash crop data. We will continue carbon mineralization, potentially mineralizable nitrogen, and litter bag decomposition studies targeting corn entry point in 2023 growing season. The economic data analysis will begin using the first two years of data. We plan to test some OMRI-approved herbicides in specific treatments to further benefit the farmers in terms of cost savings and weed control. In addition, we plan to engage a larger number of growers and scientific community in multiple Field Days and professional meetings to disseminate knowledge generated from the first two years of the project. **Impacts** What was accomplished under these goals? 1. Quantitatively compare the effects of four organic grain production systems on crop productivity, weed suppression, soil nutrient cycling, soil health, and greenhouse gas mitigation potential We identified the limitations of each of the four cropping systems at various cash and CC growth stages during our first year. Wheat yield in the first year varied from 40-50 bu/ac with no treatment effect since the field was uniformly tilled before experiment initiation. In August 2021, all crops were severely affected by drought. Sprinkler irrigation assisted corn but not single- or double-crop soybeans. The average yield of corn in T1, T2, T3 and T4 was 36.43 bu/ac, 24.96 bu/ac, 33.95 bu/ac and 38.73 bu/ac, respectively. Soybeans yield in T1 was 24.69 bu/ac. Statistics showed a positive relation between CC biomass and corn biomass. In fall 2021, tillage treatments were applied to the plots. In no-till treatment plots, residue was mowed using a flail mower and planted directly into the crop residue. The CC combinations of corn and soybean entries were adjusted in response to first-year challenges. However, early season frost hindered establishment of radish, and negatively impacted wheat tillering. Triticale and crimson clover mix in T3 corn, and red clover and timothy mix in T4 corn failed to establish properly due to planting in thick residue and weed competition. Late planting and a high-residue mulch layer led insufficient CC establishment in the second year. Wheat yield in the second year was 64.88 bu/ac for T1, 20.7 bu/ac for T2, 34.54 bu/ac for T3, and 29.49 bu/ac for T4. Corn and full-season soybeans were planted following the termination of CCs with a flail mower and roller crimper. Weed incursion was measured quantitatively using a quadrat at harvest and qualitatively by a mobile application called \"Canopeo\" that measures the green cover. Data analysis revealed that weeds negatively impacted the corn biomass in first year and wheat yield and biomass in second year. Mechanical approaches such as inter-row cultivations and hand mowing are being used to suppress weeds. Soil samples are being collected three times in a year (after CC termination, at the vegetative stage of a cash crop, and at harvest of a cash crop) from 0-5 cm and 5-15 cm. Analyses of collected soil samples are being conducted to quantify and compare soil health metrics and nutrient status of the cropping system treatments. According to the data from first-year corn entry, total nitrogen and total soil organic carbon steadily increased in comparison to the baseline data. Labile carbon pools, such as microbial biomass carbon, water extractable carbon, and permanganate oxidizable carbon (POXC) are considerably different among treatments. POXC demonstrated a linear association with soil organic carbon. We are also examining the carbon mineralization, potentially mineralizable nitrogen and nutrient availability in corn entry. Quantification of GHG emissions, with special emphasis on nitrous oxide (N2O), started from summer 2021 using static chamber. We started our 2021 gas sampling in early May before CC termination. Gas samples were collected weekly or twice in a week and were analyzed for N2O, CO2, and CH4 concentrations using gas chromatography. At each sampling event, volumetric soil moisture and soil temperature were measured, and soil samples were collected at 15 to 30 days interval to measure mineral N availability. In 2021, there were 48 gas sampling events and high N2O emissions were detected from the corn entry that received fertility inputs from poultry litter and CC residue. Cumulative N2O emissions from corn phase in T1 was as high as 35.1 kg N2O-N ha-1 followed by 19.6, 18.9, and 5.4 N2O-N ha-1 in T2, T3, and T4 respectively. Cumulative N2O emissions from soybean were 6.44, 2.88, 1.5, and 2.3 kg N2O-N ha-1 from T1, T2, T3, and T4, respectively. Cumulative N2O emissions from the winter wheat in 2021-2022 growing season were 3.6, 1.4, 0.8, 0.7 kg N2O-N ha-1 from T1, T2, T3, and T4, respectively. In 2022, we are continuing our gas flux measurements as in 2021 and data will be summarized at the end of growing season. In 2022, we initiated CC residue decomposition experiment in T2 corn phase to understand N2O emissions dynamics in response to N release during CC residue decomposition. Within the main corn plot, we have created a sub-plot at the plot edge to exclude poultry litter by spreading a tarp after CC mowing. Nylon litter bags were prepared with fresh CC biomass and buried at 10-cm soil depth. We plan to retrieve the litter bags at six-time intervals throughout the growing season. At each retrieval, decomposing residue samples from the bags are analyzed for mass loss and total C and N concentration. At the end of the 2022 growing season, we will fit an exponential decay model to CC residue decomposition and N release in the presence and absence of poultry litter and compare with temporal and cumulative N2O fluxes during the litter decomposition period. Ph.D. student advised by Co-PI Saha received additional funding support from the 2022 UTK Student/Faculty Research Award (SFRA) to support molecular analysis of N cycling genomic DNA abundance, N2O isotopomers, and available C and N to gain deeper insights on changes in microbial pathways and their contribution to N2O emissions during progressive CC residue decomposition from organic cropping systems. 2. Identifying common pest and disease issues in organic corn, soybean and wheat systems, and determine which management scenarios effectively control them Many pests were identified in corn last year, and towards the end of the growing season corn earworm and fall armyworm were identified as a major problem, so this year pheromone traps were installed in the plots to supplement visual scouting for corn earworm, southwestern corn borer, fall armyworm, and European corn borer. Moist conditions at the harvest stage have succumbed wheat to sooty mold and corn to smut last year affecting the yield drastically. Weeds in alley ways were providing optimal conditions for insect pests to thrive, therefore alley ways are being mowed regularly this year. Based on this year's disease and pest infestation, next year's management plans and OMRI-approved product use will be evaluated. 3. Conduct a comparative economic analysis to identify the most profitable organic cropping rotation Co-PI Smith, and Ph.D. supervised by Dr. Jagadamma have designed worksheets to document the total input costs such as the manual and skilled labor hours, machinery working hours, cost of seeds and fertilizers, and output costs such to account for carbon and nitrogen credits from CC residues and yield produced from cash crops. Smith will lead the economic analysis and metrics to evaluate cropping systems. 4. Integrate the knowledge generated into Extension and education programs that aim to improve producers' awareness and adoption of organic grain production During the \"Organic Crops Unit Field Day 2022\" at the field site in Knoxville, the success of CCs, the benefits of cover cropping, and changes in soil parameters were presented to farmers using data from the first year. Nearly 50 farmers were briefed on the opportunities and challenges of organic grain crop production and given an on-site poster presentation and field tour. Ph.D. student supervised by Dr. Jagadamma visited Sequatchie Cove Farm in central Tennessee to assess the situation of the cultivating organic grain crops in their field and will be visiting Mr. Marlin Martin's farm, who is a local organic grain and vegetable farmer in east Tennessee. Also, he spoke with the staff at the Caney Fork Farm in central Tennessee about organic grain production operations, challenges, and efforts to overcome them. The MTSU team provided 35 high school agricultural teachers with on-site instruction and demonstrations in organic grain production. **Publications** - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Neelipally RTKR., Saha D., Cui S., Hawkins S.A., Jagadamma S. 2022. Designing efficient organic grain rotation systems for soil health and crop productivity in Tennessee. American Society of Agronomy Southern Branch Annual Meeting, February 12-14, New Orleans, LA (poster). - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Neelipally RTKR., Ouma W., Ownley B.H., Jagadamma S. 2022. Assessing the role of plant-growth promoting microbial species from cow manure based organic formulations. American Society of Agronomy Southern Branch Annual Meeting, February 12-14, New Orleans, LA (oral presentation). - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Chhetri A, Jagadamma S, Saha D. 2022. Soil nitrous oxide emissions during establishment of organic grain cropping systems in Tennessee. ASA Southern Branch Annual Meeting, 12-14 Feb, New Orleans, LA. (poster). - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Neelipally RTKR., Chhetri A., Saha D., Shawn A.H., Jagadamma S. 2022. Conservation tillage in organic grain systems: challenges and opportunities. Field day 2022, Organic Crops Unit, East Tennessee AgResearch and Education Center (ETREC), Knoxville, University of Tennessee (oral presentation and field visit).

PROGRESS

2020/09 TO 2021/08 Target Audience:Our major target audiences for this project included 1) organic farmers who primarily grow corn and soybean in the southeastern United States, and 2) students and agricultural professionals who are interested in organic grain production. In the first year of this project, we mainly focused on establishing two field experiments. We recruited one full-time Ph.D. student, one part-time Ph.D. student, one undergraduate student, and one part-time research associate, as proposed in the project. We also recruited another full-time Ph.D. student to work in this project with funding support from other sources. More than 50 students at Middle Tennessee State University (MTSU) have enrolled in courses covering content modules in organic crop production (PLSO 3330 Field Crop Production and PLSO 4310 Forage Crop Production) and were exposed to the principles and concepts related to organic cropping system design, cover cropping, and crop rotation. At the experimental site in East Tennessee AgResearch and Education Center (ETREC)- Organic Crops Unit (OCU) in Knoxville, TN, the farm manager William Lively in collaboration with ETREC- Plant Sciences Unit farm manager B J DeLozier coordinated the field preparation and all field management activities such as tillage, manure application, seeding, and cover crop termination. At the MTSU site in Murfreesboro, TN, the field experiment has been managed by Co-PI Song Cui and part-time research associate Andrew Nevins. The lead PI

Sindhu Jagadamma, and Co-PI Debasish Saha have recruited Ph.D. students Ravi Teja Neelipally (funded by the grant) and Arjun Chhetri (funded by other sources). Ravi Neelipally is leading the agronomic and soil health components of the project and Arjun Chhetri is leading the greenhouse gas measurement component of the project. Co-PI Bonnie Ownley recruited Wilson Ouma, a part-time Ph.D. student to undertake the pest and disease component of the project. Changes/Problems:During the field preparation stage, we realized that MTSU site doesn\'t have sufficient certified area for laying out the full design of this experiment. Therefore, one cropping system treatment (treatment \# 4) was cut from the design at this site. For this treatment, we will rely on the results from the ETREC-OCU site. This year\'s cover crop termination using roller crimper was not a great success. Increased seeding rate and late maturity of hairy vetch prior to soybean led to unsatisfactory roller crimping termination, resulting in uneven soybean stand. To address this, we will reduce the seeding rate of legume cover crops prior to legume cash crops and terminate the cover crops at 50% flowering stage of hairy vetch. Using a trial plot, we will compare the efficacy of a roller crimper and a flail mower for terminating cover crop mixtures and identify the optimal equipment and timing for next growing season. The longer growing degree days in the southeastern United States foster the growth of cover crops, which ultimately create a thick mulch layer. The standard planter settings were unable to penetrate the heavy mulch, resulting in poor seed germination. Next year, we would like to utilize row scrapers for the planter and add more weight to ensure that the seeds have appropriate soil contact. What opportunities for training and professional development has the project provided?Two Ph.D. students are being co-mentored by PIs Jagadamma and Saha for undertaking the research proposed under Objective 1. Another Ph.D. student is being mentored by Co-PI Ownley for undertaking research proposed under Objective 2. At the ETREC-OCU site, undergraduate students and research assistant Michael Evan Russell have been trained on soil, plant and gas sampling and analysis. At the MTSU site, research associate Andrew Nevins is being trained by Co-PI Cui on establishing and managing the field experiment. At both sites, several student groups and faculty members as well as university administrators visited the field experiments. Most of them had no prior experience witnessing how a systematically replicated field project was carried out and how corn and soybean could be produced without relying on chemicals. Thus, involving agricultural students in field-based projects can greatly enhance their understanding and educational experience related to organic grain crop production. How have the results been disseminated to communities of interest?Project Director Jagadamma is communicating on a regular basis with local farmers, organic producers, no-till farmers, extension agents, expert faculty from other universities and Natural resources conservation Service (NRCS) agents about this project. Recently Jagadamma and Ravi had a fruitful conversation with a faculty and graduate student from the University of Maryland who have a similar project. We shared our experiences and offered our collaboration regarding research activities. We are also using social media platforms (e.g., twitter, lab website) to share our experiences regularly through photos and short videos and disseminate our interests to general public and larger audience. Once we generate the first-year data, we will conduct multiple outreach activities to reach a broad spectrum of stakeholders. What do you plan to do during the next reporting period to accomplish the goals?The team will continue triannual soil sampling and periodic gas sampling as well as cover crop and cash crop data collection and analysis from the field experiments. The team members will begin to give Extension presentations and other outreach and education activities proposed. Based on the observations on weeds, pests, and disease scouting in Year 1, some OMRI-approved remedial measures will be tested. In addition, we will also begin economic analysis. Based on the general experience from Year 1 crop establishment at both sites, we will also make slight adjustment in planting dates, seeding rates, and machinery use.

IMPACT

2020/09 TO 2021/08 What was accomplished under these goals? 1. Quantitatively compare the effects of four organic grain production systems on crop productivity, weed suppression, soil nutrient cycling, soil health, and greenhouse gas mitigation potential The field experiments were initiated in the certified organic land at ETREC-OCU and MTSU. The fields were uniformly tilled in September 2020 and planted with different cover crop mixtures in soybean and corn entry points according to the cropping system rotation treatments. The cover crop and weed biomass were measured in December 2020 at vegetative stage and at termination in early May 2021. Cover crops varied across the cropping systems, therefore the overall biomass and weed suppression ability of the systems also altered (triticale and hairy vetch mix established better than the rest). The first-year winter wheat was planted at the same time of cover crop planting and harvested by the end of June 2021. To meet nutrient requirements for wheat, 1 ton/acre of pelleted poultry litter (PPL) was broadcasted at each split (prior to planting and at tillering stage). Due to annual rye infestation as well as lodging and sooty head mold attack caused by the strong rains and winds, the winter wheat crop was unable to be harvested; consequently, the harvest was manually recorded using 2*0.25 m2 quadrats and the remainder of the field was mowed with a flail mower. Following cover crops in spring 2021, the cash crop treatments varied in management practices such as tillage and nutrient inputs. Cover crops in chisel till and disk till treatments were mowed and the residues were tilled by off-set disk up to 30 cm and pick-up disk up to 5 cm respectively. In the no-till treatments, cover crops were roller crimped 3 times to have a satisfactory termination. Corn was planted after applying 2 tons/ac PPL as basal dose whereas soybean was planted directly. Except for the treatment with no external inputs, corn was side-dressed with 4 tons/ac PPL. All the inputs and management practices comply with the guidelines of National Organic Standards Board (NOSB). The tillage intensity varied across the cropping systems, but all planting and termination techniques were based on the standard crop management guidelines established by The University of Tennessee organic and sustainable crop production program. There was critical infestation of ivyleaf morning-glory (Ipomoea hederacea), johnsongrass (Sorghum halepense) and alfalfa (Medicago sativa) in the experimental plots, therefore they were controlled to economic levels using manual weeding. There were also other weeds such as annual rye (Lolium multiflorum), copperleaf (Acalypha persimilis), crabgrass (Digitaria ischaemum), giant foxtail (Setaria faberi), bull thistle (Cirsium vulgare), vetches (Vicia spp.) and some clovers (Trifolium spp.). We collected soil samples before the experiment from 0 to 60 cm depth and separated into four depth increments (0-5 cm, 5-15 cm, 15-30 cm and 30-60 cm) to characterize the baseline soil health and nutrient status (September 2020). Soil samples were again collected from 0 to 30 cm depth in three depth increments (0-5 cm, 5-15 cm and 15-30 cm) to characterize how the first season of cover crops affected soil health and nutrient status (May 2021) and to assess the effect of management practices at the row crop vegetative stage (July 2021). For greenhouse gas collection, we installed one PVC gas chamber in each of the 48 plots in April 2021. We started our 2021 gas sampling campaign in early May before cover crop termination. Gas samples were collected weekly or twice in a week depending on the management practices (for example - tillage, planting, manure application) and the weather events (for example precipitation). We have so far conducted 12 gas sampling campaigns and analyzed \~1500 gas samples. Gas sampling intensity followed the trend corn \> soybean \> wheat and was informed by the measured gas concentration data. We anticipate conducting at least 20 gas sampling events during the 2021 growing season. At each gas sampling, volumetric soil moisture and soil temperature at 10-cm depth were measured by portable soil moisture sensor and soil thermometer. We have also collected six periodic soil samples from 0-15 cm soil depth to measure mineral N availability. The soil samples were extracted with KCl to determine nitrate and ammonium concentrations using a spectrophotometer. 2. Identifying common pest and disease issues in organic corn, soybean and wheat systems, and determine which management scenarios effectively control them In the first year of the organic grain project, we have already set up systems to enable us to scout and diagnose diseases in corn, soybean, and wheat. Scouting is done on a weekly basis and any pests seen recorded. In soybean, we use standard 15-inch sweep net and record the numbers of the pests collected in 25 sweep nets. In soybean fields we have been observing high numbers of three corned alfalfa hoppers, which has been causing girdling and death of some young plants. These pests will be a challenge especially in reduced tillage fields. Other pests that have been observed in soybean fields include, bean beetle, Japanese beetle, grasshoppers, dectes stem borer, alfafa looper, stink bugs and blister beetles. In corn pests are mostly scouted visually and several pests that have been observed include grasshoppers, stinkbugs, Japanese beetles, southwestern corn borer, fall armyworm, corn earworm, leaf miners and corn rootworm. For diseases, any plant showing symptoms or signs of disease samples are taken and cultured in PDA media. The culture is observed under a microscope and then PCR is done, and the product sent for sequencing. So far, we have several cultures collected that are about to be sequenced for proper identification. We are also now incorporating pheromone traps such as European corn borer, southwestern corn borer, Japanese beetle and fall armyworm to monitor the adults to aid us in decision making on the control of the pests. We have also incorporated technology in our scouting program, where we use apps such as farmdok, which helps record the pests in real time and the exact position where the pest is located, other apps include picture insect which helps with identification of insects and plantNet with identification of weeds. We are continuing to monitor for any other type of pest that we might incur this year to be in a better position to control next year. 3. Conduct a comparative economic analysis to identify the most profitable organic cropping rotation Ph.D. student Neelipally is working with Co-PI Aaron Smith to design excel worksheets to document detailed input and output costs by treatments. The excel workbook reflects the reports on all three years of the transition period of this experiment. The economic analysis will be starting in Year 2. 4. Integrate the knowledge generated into Extension and education programs that aim to improve producers\' awareness and adoption of organic grain production Extension activities have not started yet as we do not have sufficient data yet. However, the team members have been introducing this project to producers and other stakeholders as opportunities arise (e.g., field trip to Sam Harvey\'s Windy Acres Organic Farm in Nashville, TN and communication with local organic farmer Matt Nielsen and a regenerative farmer from North Dakota Gabe Brown). The team at MTSU acquired a small-plot roller crimper that has already been used for cover crop termination during the 2020-2021 season.

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Diversifying Organic Cotton Production in Semi-arid Environments of Texas

Accession No.	1023616
Project No.	TEX09850
Agency	NIFA TEX\
Project Type	OTHER GRANTS
Project Status	NEW
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Proposal No.	2020-02286
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Investigator(s)	De Laune, P.
Performing Institution	TEXAS A&M UNIVERSITY, 750 AGRONOMY RD STE 2701, COLLEGE STATION, TEXAS 77843-0001

NON-TECHNICAL SUMMARY

Texas is the leading state in organic cotton and peanut production. Through our surveys, organic growers have identified weed control and soil management as a top area of concern. Cover crops, crop rotation, and compost management are tools that can potentially address these concerns. Producers are hesitant of using cover crops in semi-arid environments due to soil water use and adoption of crop rotation is also low in organic cotton systems. Our goal is that results from this project will empower organic growers to make informed choices on inputs that will result in effective weed management, higher and more consistent yields, improved soil health and function, and improved nutrient cycling. We propose to conduct research in leading organic regions within two varying ecoregions: Vernon in the Texas Rolling Plains, and Lubbock in the Southern High Plains. We will determine the effects of commonly used cover crops and crops that may not be typically used as cover crops but may have the potential to improve weed suppression when used as a cover crop. We will also evaluate the potential for other crops as an organic commodity to increase crop rotation and diversity. Through these trials, measurements will be made to determine how well the soil captures and stores precipitation or irrigation water, cycles nutrients, influences soil microbial diversity and how agronomic production and economic returns are affected. As the most common way to incorporate dry compost and/or manure is the incorporate with tillage after surface application, there is an increased likelihood of increasing greenhouse gas emissions and/or degrading soil resources. Hence, a novel subsurface compost applicator will be used to evaluate the effect of compost application rate and placement on soil nutrient cycling, greenhouse gas emissions and agronomic production. Field trials and collected information will be shared with students, growers, researchers, county agents, natural resource managers, and regional public officials.

OBJECTIVES

Our long-term goal is that results from this project will empower organic growers to make informed decisions on inputs that will result in effective weed management, higher and more consistent yields, improved soil health, and carbon (C) sequestration. We propose to conduct research in leading organic regions within two varying ecoregions: Vernon in the Texas Rolling Plains of North Texas, and Lubbock in the Southern High Plains. We will focus on the following specific objectives: 1) Determine the effects of traditional and non-traditional cover crops and crop rotation on stored soil moisture, soil health, and agronomic and economic viability of organic systems; 2) Determine the effects of compost application rate and placement on soil nutrient cycling, greenhouse gas emissions and agronomic and economic viability of organic systems; and 3) Disseminate information to students, growers, researchers, county agents, natural resource managers, and regional public officials on the production potential, ecological services, financial viability of evaluated organic cropping systems.

APPROACH

Research trials will be initiated on transitioning organic land at the Texas A&M AgriLife Research and Extension Center at Vernon and Lubbock. The study will be conducted under center pivot sprinkler irrigation at the Vernon location. The irrigation system consists of low drift nozzles on 0.76 m spacing with a deflector pad for multiple stream application and a bubble pad option. Furrow irrigation will be utilized at the Lubbock location. Cotton, peanuts and sesame will be planted mid-May to mid-June each year using a four-row vacuum planter placed on 1 m row spacing. Organic cotton will be planted at 10 seeds m-1. Organic peanuts (variety ACI236) will be planted at 16 seeds m-1 during year 2 of the cotton/peanut rotation. Sesame will be planted at 3.4 kg ha-1 during year 2 of the cotton/sesame rotation using a variety recommended by Equinom representatives. Wheat will be planted at 67 kg ha-1 following cotton harvest in year 1 using a box drill on 25 cm row spacing. A forage sorghum or corn will be planted following wheat harvest in year 2 and will be harvested as a silage or hay crop 75-100 days after planting. Tillage operations will be performed as necessary, which will be heavily dependent upon weed pressure. The goal is to minimize tillage as much as possible, as we understand a true no-till system will probably not be attainable. Due to treatment effects, the number of tillage operations may vary among treatments. Mechanical mowing may be utilized for weed control in peanuts. Organic approved cover crops will be planted using a 4-m grain drill within one week after harvest cash crops. Cover crops will be clipped from a 1-m2 area prior to termination and measured for biomass production and C/N content using a combustion analyzer. Compost will be obtained from a regional composting company that composts beef cattle feedlot manure, dairy manure, and poultry layer manure. Compost will be applied at 4.5 Mg ha-1 annually in mid to late-spring (April-June). Assessments will be carried out to assess weed cover, frequency, and biomass. Evaluations will be carried out using two complementary methods: 1) non-destructive, visual cover class rating and 2) destructive subsampling of weeds for biomass. Weed biomass will be collected from three random 1-m2 quadrats in each plot and visual control (cover, frequency, composition by cover) will be determined in at least three 1-m2 quadrats from the middle two rows of each plot. A neutron moisture meter will be used to monitor stored soil moisture in three of four reps for each treatment Aluminum access tubes will be placed 10 cm from the row in each plot to a depth of 150 cm. Stored soil moisture will be measured at 20 cm depth increments from 0 to 140 cm bi-weekly from March-May and at critical crop growth stages during the remainder of the year (reproduction stage, harvest, cover crop planting. Soil samples will be collected from each experimental plot prior to cash crop planting each year. Samples will be collected at depths of 0-10, 10-20, 20-30, 30-60, and 60-90 cm in years 1 and 3. Soil samples will be collected from 0-10, 10-20, and 20-30 cm in year 2. Bulk density will also be determined annually using the hydraulic soil probe to determine mass nutrient balances. Soil organic C (SOC), total C and total N will be determined using dry combustion (Elementar Vario Max CN Analyzer). Water-extractable organic C and water-extractable N, which has shown to be more sensitive to management practices, will be determined from 4 g of dry soil sample with 40 ml of deionized water and shaking for 10 minutes on a mechanical shaker. Inorganic ammonium and nitrate will also be determined for water extractions using a segmented flow analyzer. Soil aggregates will be measured using digital imaging (SLAKES APP). In addition, in years 1 and 3, samples collected at 0-10 and 10-20 cm will be shipped and analyzed for total living microbial biomass, total fungal biomass, total mycorrhizal fungal biomass, total bacterial biomass, and gram (+, -) bacteria using phospholipid fatty acid (PLFA) analysis by solid phase chromatography according to the methods of Clapperton et al. (2005) and Zelles (1997).Budgets will be developed based on data from experimental research plots and primary input and machinery information obtained from producers and members of the organic cotton industries in Texas. Input and feedback from producers and members of the organic industry will be essential for validating the accuracy of the economic analysis. The budgets will entail all aspects of organic crop production (seed, fertility, irrigation, machinery, etc.) and will include both operating (variable) and ownership (fixed) expenses related to each organic production system. Returns above operating and ownership expenses will be calculated for alternative organic prices, and comparisons will be made with conventional cotton systems. Objective 2: Determine the effects of compost application rate and placement on soil nutrient cycling, greenhouse gas emissions and agronomic and economic viability of organic systems.This portion of the study will be conducted at the Texas A&M AgriLife Research and Extension Centers in Vernon and Lubbock as described in objective 1. Compost application treatments will be: 1) Broadcast surface applied at 8.96 Mg ha-1; 2) Subsurface applied at 4.48 Mg ha-1;3) Subsurface banded at 8.96 Mg ha-1. Similar management practices will be used as outlined under objective 1. A rye cover crop will be planted at 34 kg ha-1 in the fall of 2020 and terminated via tillage and/or roller crimping in mid to late spring (April). Crop stand establishment will be determined by conducting plant counts from 3-m of a planted row three weeks after planting. Crops will be harvested as outlined above to determine yields. Compost will be obtained from a regional composting company and applied at the same time using each method for a direct comparison of compost placement and rate. The application will occur just prior to cover crop termination and before cotton planting during the first two years. The Subsurfer applicator will be used to knife-in compost at least 5 cm from the seed row. Compost will be analyzed for total C, total N, water-extractable P and N. Weed pressure will be monitored during the two cotton growing seasons, wheat and forage growing seasons. Approaches for soil sampling and analyses of C, N, P, WEOC, and WEON will be the same as those for the abovementioned methods. Soil gas fluxes of CO2, N2O, NO, and CH4 will be measured at locations bi-weekly prior to (starting in March) and after terminating cover crops (April and May) and then monthly throughout the target crop growing season and until planting cover crops. Gas measurements will also be collected 7 and 14 d following broadcast and subsurface banded compost applications. A Gasmet DX-4040 Fourier Transform InfraRed-Multicomponent Gas Analyzer (FTIR; Gasmet Technologies Inc., La Prairie, QC, Canada) integrated with a Li-Cor 8100-103 20-cm survey chamber will be utilized to measure trace gas fluxes at the soil:atmosphere interface. Progress 09/01/20 to 08/31/24 Outputs Target Audience:Organic producers were initially the primary targeted audience. Growers connected through the Texas Peanut Producers Board, Texas State Support Committee for Cotton Inc., and Texas Organic Cotton Marketing Cooperative were consulted prior to the project and remained comprised of research findings throughout the project. During the project, regenerative agriculture and climate-smart agriculture became terms describing the latest effort in sustainable agriculture. As a result, our targeted audience grew to include all farmers as the interest in potential carbon credits and/or climate-smart agriculture payments became a topic of discussion. Furthermore, state and federal agencies became an interested target audience due to the interest in how organic agriculture may differ from regenerative agriculture or climate-smart agriculture and how these systems may compare and contrast. Research findings can help shape policy and/or management guidelines for regenerative practices. During the project, the Texas A&M University System created a new Organic Agriculture Extension Specialist position, which brought added attention to the project and a wider audience from different crops and stakeholders in general that were interested in agricultural stewardship. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?The project provided numerous opportunities for project personnel, state and federal agency personnel, and stakeholders. During the project, a Organic Extension Specialist was employed, bringing more focused attention to organic agriculture and the project. While many presentations provided by lead project personnel focused on regenerative agriculture approaches (which is the expertise of the project team), organic agriculture was discussed as a comparisonof non-organic approaches. A project website was developed as well as a video link to presentations discussing regenerative and organic agricultural systems. A series of \"Organic Get Together\" meetings were developed, which had the greatest attendance at the fourth and final meeting during the project period. Information from this project was also used to develop educational materials for K-12, higher education, and a master steward soil program, although not fully completed and available during the project period. How have the results been disseminated to communities of interest?Most of this information is provided under opportunities for professional development. Most notably, social media, in-person workshops, field days, state and regional stakeholder meetings, and professional scientific meetings. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Objective 1. Determine the effects of traditional and non-traditional cover crops and crop rotation on stored soil moisture, soil health, and agronomic and economic viability of organic systems; In general, the major finding of this study was that weed management is critical to success in organic agriculture within water-limited environments of West Texas. Although repeated tillage operations were conducted and even clean-till operations with replanting were conducted in some years, weeds overwhelmed cash crops. Hence, transitioning to organic agriculture should be done on well-managed weed free fields. Our results highlight that changes in soil health parameters because of organic transition are influenced by ecoregion, land history, and management decisions (plant selection, compost application frequency, planting, and termination timing). In addition, seed quality for major crops in these regions (peanut and cotton) should be evaluated to ensure successful germination and stand establishment. Field studies were established in the Texas High Plains (THP) at Lamesa, Texas, and in the Texas Rolling Plains (TRP) at Vernon, Texas, from 2021-2023. The cropping systems at each site were continuous cotton (Gossypium hirsutum L.) (CC), cotton/peanut (CP) (Arachis hypogaea L.) at Lamesa and cotton/mungbean (Vigna radiata L.) (CM) at Vernon, cotton/sesame (Sesamum indicumL.) (CS), and cotton/wheat/forage sorghum sudangrass (Sorghum bicolor x Sorghum sudanense) (CWH). The cover crop treatments were rye at 17 kg ha-1 (Rye17), rye at 34 kg ha-1 (Rye34), fennel/fenugreek (FF) mix at 8.5/8.5 kg ha-1, rye/fennel/fenugreek (RFF) at 25/6/6 kg ha-1. Soils at both sites were characterized for key physical, chemical, and biological soil health parameters, and crop yields and cover crop herbage mass were determined annually. Additionally, at Lamesa, stored soil moisture and CO2 emissions were measured in 2022, and weed cover in 2023. The study demonstrated the challenges of organic crop production in the THP for biomass production, weed control, water storage, and C losses. Following three years of organic management, weed pressure was overwhelming, and crops were not able to overcome water limitations, resulting in crop failure in two out of three years. The inclusion of forage sorghum sudangrass in the crop rotation showed the most promise for reducing weed pressure. Further, allowing forage sorghum residues to remain on the soil surface over winter and spring resulted in significantly greater stored soil moisture than the use of a living cover crop. The high herbage mass production of forage sorghum sudangrass resulted in greater CO2 emissions than the other cropping systems, but C inputs from residues replaced approximately 50% of C lost. Outside of treatment effects, weed respiration has the potential to drive CO2 losses, which could slow C accumulation in organic cropping systems. We found evidence in both the TRP and THP that crop rotation has benefits over cotton monoculture for soil health parameters. At Vernon, after three years of crop rotation with cover crops and compost application, SOC stock was increased by 14 to 43%. Improvements in MWD and soil N were also observed. Increases in total microbial biomass, as well as an abundance of G+ bacteria, AMF, total fungi, and actinobacteria, indicate potential benefits of conservation practices (crop rotation, cover crops, compost) for soil biological health and C storage. At Lamesa, improvements in MWD, Mehlich III P, total microbial biomass, and abundance of AMF, G-, and G+ bacteria were observed. Soil TN was unaffected, and WEON decreased over the trial period. SOC stock increased by 22 to 31% at Lamesa. At both sites, changes in physical properties were inconsistent across depths and crop rotations. Still, the improvements in MWD signify potential improvements that may become more apparent after several years of conservation management. Crop yields and cover crop herbage mass were generally low because of drought and weed pressure. Still, the cropping system most influenced changes in soil health parameters at both sites. Mean weight diameter (MWD), total microbial biomass, and certain microbial communities (AMF, G+ bacteria) were most improved during the transition period to organic production. Objective 2. Determine the effects of compost application rate and placement on soil nutrient cycling, greenhouse gas emissions and agronomic and economic viability of organic systems; Treatments evaluated in TRP and THP included an unfertilized control, broadcast application of compost at 8.96 Mg/ha, and subsurface application at 4.48 and 8.96 Mg/ha. All applications were made post-planting of cotton. Daily CO2--C fluxes peak around 30 lbs of C per acre per day. The rye over crop above ground herbage mass averaged 312 lbs per acre in the cotton-rye cover system, which equates to roughly 134 lbs of C per acre. This means that only 5 days of peak CO2 flux is needed to release all C contributed by aboveground rye herbage mass. Carbon dioxide flux after subsurface fertilization is greater over the fertilizer band than unfertilized row area across all systems (minus the unfertilized fallow). Between the continuous cotton and cotton-rye cover systems, the difference between fertilized and unfertilized area is greater in the continuous cotton system. It is likely that the decomposition of rye biomass had already stimulated microbial respiration in the cotton-rye cover system, since rye biomass is a source of C and can act as a slow release N source. The lower input continuous cotton system may have lower residual N during the middle of the cotton growing season, and may experience greater simulation after addition of N fertilizer as a result. Increased irrigation resulted in increased CO2 flux across all systems. This is not surprising because water influences microbial activity, usually increasing activity as soil moisture increases. The application approach did not impact crop yields, as yields were hindered by drought and weed pressure. When banding high concentrations of manure and/or compost, consideration should be given to the potential for increased GHG emissions even when the placement is below the soil surface. Objective 3.Disseminate information to students, growers, researchers, county agents, natural resource managers, and regional public officials on the production potential, ecological services, financial viability of evaluated organic cropping systems. Information was provided to traditional clientele, which is a small percentage when thinking about only organic production. However, with an increasing interest in regenerative agriculture and/or climate smart practices more clientele were reached over time when comparing organic management to other regenerative approaches. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Boogades, N., C. Cobos, J.A. Burke, P.B. DeLaune, W. Keeling, and K.L. Lewis. 2023. Carbon dioxide emissions from regenerative cropping systems in the Texas Plains. ASA-CSSA-SSSA International Meetings. St. Louis, MO. 29 October-1 November 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Selph, L., K.L. Lewis, and P.B. DeLaune. 2023. Crop rotation and cover crop effects on soil moisture in a transitional organic system. ASA-CSSA-SSSA International Meetings. St. Louis, MO. 29 October-1 November 2023 Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Boogades, N., K.L. Lewis, P.B. DeLaune, T. Gentry, and E. Pierson. 2023. Cover crop effect on soil health during organic transition in cotton-peanut rotation in the Texas Plains. ASA-CSSA-SSSA International Meetings. St. Louis, MO. 29 October-1 November 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Selph, L., K. Lewis, and P. DeLaune. 2024. Development of recommended organic crop rotation with cover crops in the semi-arid Texas High Plains. Beltwide Cotton Conference, Ft. Worth, TX. 3-5 January 2024. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: DeLaune, P., K. Lewis, N. Boogades, and E. Kimura. 2024. Evaluation of regenerative agricultural practices in peanut/cotton rotations. Beltwide Cotton Conference, Ft. Worth, TX. 3-5 January 2024. Progress 09/01/22 to 08/31/23 Outputs Target Audience:During this year of the project, peers in the scientific community were the key target audience. This audience included a diverse and multidisciplinary group, including soil scientists, agronomists, weed scientists, and economists.

Graduate students comprised a major portion of the committed time and audience as graduate students involved directly in this projectprovided several presentations in graduate student competitions at regional and national conferences. Additionally, organic cotton and peanut producers were also kept apprised of project progress and findings through stakeholder and/or board meetings. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?An additional graduate student was trained on laboratorymethods to determine organic and total C, soil test phosphorus, water extractable organic C and N in soil. In addition, students were trained to use related analytical equipment within the lab to determine each listed constituent. Three different students presented presentations related to this project at various scientific?meetings. How have the results been disseminated to communities of interest?Preparations have began to develop disseminationmaterials to communities of interest. A draft LaboratoryManual has been developed by one of the graduate students who is a soil science instructor at West Texas A&M University. This student/instructor has also developed a field research site consistingof organic and conventional production for hands-on classroom learning. What do you plan to do during the next reporting period to accomplish the goals?Crop harvest will be completed in fall 2023 along with ongoing soil health analysis. Soil health analysis includes soil chemical, physical, and microbial properties as well as soil water use and storage. All data will be compiled and provided to a risk economistto quantifyeconomic net returns for the evaluated systems. Information will be included in a soil fertility lab manual for use at West Texas A&M University. A final extension publication using traditional methods (printed fact sheet) and videos will also be completed. Project summaries will be completed and shared by project leads and graduate students at stakeholder and scientific meetings throughout the final year. Impacts What was accomplished under these goals? Determine the effects of traditional and non-traditional cover crops and crop rotation on stored soil moisture, soil health, and agronomic and economic viability of organic systems. During year 1 of the study, cotton was the common crop planted across all four crop rotation scenarios. Evaluated scenarios include 1) continuous cotton with a rye cover crop; 2) cotton-sesame rotation; 3) cotton-peanut rotation; and 4) cotton-wheat-annual forage rotation. Rotations 2-4 cover crops of 1) cereal rye planted at 34 kg ha-1; 2) cereal rye planted at 25 kg ha-1 plus 12 kg ha-1 of a 50/50 fenugreek/fennel mix; and 3) 17 kg ha-1 of a 50/50 50/50 fenugreek/fennel mix. The fennel/fenugreek mix is planted in the spring. For this reporting period starting September 2022, the second year of the rotation had been implemented at sites in Lubbock and Vernon, TX. Existing rotations in Fall 2022 included continuous cotton, sesame following cotton, a cover crop/silage mixture consisting of sorghum-sudangrass and forage cowpeas following cotton/wheat, and either peanut (Lubbock) or mungbeans (Vernon) following cotton. At each location, severe weed pressure was a limiting factor to stand establishment and productivity. At Lubbock, insect pressure was detrimental to sesame production. At Vernon, palmer amaranth infestation resulted in two re-plantings. Although the system was clean tilled three times, once before the initial planting and twice before re-planting, weed pressure remained high into the fall. In addition to weed pressure, exceptional drought conditions were experienced at each location. Hay, sesame and mungbeans were harvested at the Vernon site whereas cotton was deemed a failure due to weed pressure. At Lubbock, only cotton was harvested due to a combination of climate, insect and weed pressure. Rye was planted as a cover crop at each location in fall 2022 after respective harvests. The fenugreek/fennel mixture was planted alone or within standing rye cover crop in spring 2023. Rye performed well at each location. In contrast, the fennel/fenugreek mixture did not establish well at either location alone as a cover or interseeded within the rye cover crop. Cotton was planted at each location in late spring/early summer 2023. Stand establishment of organic cotton seed was extremely poor at each location. Seed quality should be considered as an area of concern for future organic research projects as conventional cotton varieties in adjacent plots established well. Cotton was replanted in Vernon in early July, which is well past ideal planting dates. Throughout the reporting period, soil moisture was monitored, and soil samples were collected for soil nutrient and soil health analysis. Cover crops did not significantly reduce soil moisture compared to fallow. Crop rotation resulted in higher soil moisture content compared to continuous cotton throughout the season. Moisture use, weed pressure, cover crop biomass, and crop yields will be correlated with soil health measurements once completed. Various weed management strategies have not been successful to control palmer amaranth, including delayed planting, repeated tillage operations, re-planting, and use of finger weeders. Objective 2: Determine the effects of compost application rate and placement on soil nutrient cycling, greenhouse gas emissions and agronomic and economic viability of organic systems This portion of the project was initiated with the planting of a rye cover crop in fall 2022 at both the Lubbock and Vernon locations. Greenhouse gas fluxes were monitored throughout the 2022 and 2023 cotton growing season (May-October). Compost applications were made 3-6 weeks after cotton emergence. Compost treatments included a surface broadcast application rate of 8.96 Mg ha-1. The surface broadcast application was not incorporated as applications were made post-germination. Subsurface applications were made post-emergence at about 15 cm from the row and 15 cm deep at rates of 4.48 and 8.96 Mg ha-1. These applications occurred on the same plots as 2022. In 2023, poor stands due to seed quality led to re-planting at the Vernon location while it was deemed too late to re-plant at the Lubbock location. Subsurface applications decreased soil nitrate concentrations relative to broadcast applications. It is hypothesized this is due to an increase in microbial activity and immobilization/greater use of the nitrate pool. In contrast, significant increases in soil ammonium were observed early in season in subsurface treatments at Vernon whereas broadcast and subsurface applications had similar nitrate content. Initial data from the 2022 growing season indicated significant differences in GHG fluxes only at Vernon, where high subsurface compost applications had greater fluxes. Collected data from 2023 are undergoing analysis. Objective 3: Disseminate information to students, growers, researchers, county agents, natural resource managers, and regional public officials on the production potential, ecological services, financial viability of evaluated organic cropping systems. The first full crop season cycle was completed in year 2 of the project. These initial findings have been presented at the annual ASA-CSSA-SSSA meeting, Cotton Beltwide Conference, Texas Plant Protection Conference, and Southern Branch - ASA annual meeting. Abstracts were submitted to the Soil and Water Conservation and ASA-CSSA-SSSA Annual Meetings. Concepts and goals of the project were shared with organic commodity groups. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Selph, L., K.L. Lewis, and P.B. DeLaune. 2022. Crop rotation and cover crop effects on greenhouse gas flux in a transitional organic system. ASA-CSSA-SSSA International Meetings. Baltimore, MD. 6-9 November 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Babcock, R.E., L.E. Selph, K.L. Lewis, P.B. DeLaune, C. Bednarz, S. Singh, and L. Slaughter. 2022. Influence of crop rotation and cover crop selection on soil moisture flux in a transitional organic system. ASA-CSSA-SSSA International Meetings. Baltimore, MD. 6-9 November 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Boogades, N., K.L. Lewis, T.J. Gentry, and P.B. DeLaune. 2022. Composted manure rate and placement effects on greenhouse gas emissions in semi-arid cotton. ASA-CSSA-SSSA International Meetings. Baltimore, MD. 6-9 November 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Boogades, N., L. Ellman-Stortz, K.L. Lewis, T.J. Gentry, P.B. DeLaune, and W. Keeling. 2022. Soil health in organic and conventional cotton-peanut rotations in the Texas Plains Region. ASA-CSSA-SSSA International Meetings. Baltimore, MD. 6-9 November 2022. Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: Boogades, N., L. Ellman-Stortz, K.L. Lewis, P.B. DeLaune, T.J. Gentry, W. Keeling, and E. Pierson. 2022. Soil health and economics through organic transition in the Texas Plains. Texas Plant Protection Association Annual Conference. College Station, TX. 6-7 December 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Keeling, W., K.L. Lewis, P. DeLaune, E. Kimura, and T. Gentry. 2023. Economic analysis of organic cotton and peanut production in the Texas High Plains. Beltwide Cotton Conference, New Orleans, LA. 10-12 January 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Selph, L.E., K.L. Lewis, and P. DeLaune. 2023. Allelopathic cover crops for alternative weed control in a semi-arid transitional organic system. Beltwide Cotton Conference, New Orleans, LA. 10-12 January 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Boogades, N., K.L. Lewis, T.J. Gentry, and P.B. DeLaune. 2022. Greenhouse gas emissions following manure application in organic cotton. Beltwide Cotton Conference, New Orleans, LA. 10-12 January 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Selph, L., K.L. Lewis, and P.B. DeLaune. 2023. Crop rotation and cover crop effects on soil moisture in a transitional organic system. Southern Branch-American Society of Agronomy Annual Meeting, Oklahoma City, OK. 4-6 February 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Boogades, N., K.L. Lewis, P.B. DeLaune and T.J. Gentry. 2022. Manure rate and placement effects on gas emissions and nutrient conservation in semi-arid organic cotton. Southern Branch-American Society of Agronomy Annual Meeting, Oklahoma City, OK. 4-6 February 2023. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: Organic cotton and peanut producers were reached through a field day occurring onJan. 26, 2022 with 80 participants. The audience was primarily organic peanut producers, who typically use cotton as a rotational crop. The audience was introduced to the concept, objectives, and overall goal of the project. The Texas Peanut Producers Board and Texas Organic Cotton Marketing Cooperative were also updated on project progress. Scientific peers and students were updated on project findings at conferences. Changes/Problems: Drought has been a lingering issue, but is real world and common to the study region. An EF-3 tornado struck the Texas A&M AgriLife Research and Extension Center at Vernon on May 4, 2022. Full repairs are not expected until 2024. Due to lack of office space, graduate students were not able to reside at the Vernon Center over the summer as planned. Hence, a reduced workforce was available to manage the plots at Vernon. However, studies continued and data were collected at the site throughout the period. As lab facililites were also affected, some analysis has been delayed as temporary labs were setup. Full analytical capabilities should be avaiable in period 3. What opportunities for training and professional development has the project provided?Two graduate students were trained to collect soil moisture using Neutron Moisture Meter technology as well as collect GHG emissions using FFIR technology. These students either presented initial findings at conferences or submitted abstracts to present initial findings at conferences scheduled during year 3 of the project. These presentations have exposed peers in the scientific communtity to initial project findings. How have the results been disseminated to communities of interest? Producers have been introduced to project concept, goals, and issues at stakeholder meetings and a field day, although the project was not specifically an agenda item. What do you plan to do during the next reporting period to accomplish the goals? Phase two of the crop rotation cycles will be collected and the third year of cover crop treatments will be planted during the next period. Soil, herbage mass, forage, and/or grain samples will be processed, analyzed and interpreted during the next period. Information will also be diessminated through social and electronic resources so best management practices for transitioning organic cotton systems can be readily available to interested parties. As data analysis continues, results will be presented at multiple conferences during period 3. **Impacts** What was accomplished under these goals? Objective 1: Determine the effects of traditional and non-traditional cover crops and crop rotation on stored soil moisture, soil health, and agronomic and economic viability of organic systems. During year 1 of the study, cotton was the common crop planted across all four crop rotation scenarios. Evaluated scenarios include 1) continuous cotton with a rye cover crop; 2) cotton-sesame rotation; 3) cotton-peanut rotation; and 4) cotton-wheat-annual forage rotation. Rotations 2-4 cover crops of 1) cereal rye planted at 34 kg ha-1; 2) cereal rye planted at 25 kg ha-1 plus 12 kg ha-1 of a 50/50 fenugreek/fennel mix; and 3) 17 kg ha-1 of a 50/50 50/50 fenugreek/fennel mix. The fennel/fenugreek mix is planted in the spring. Cotton yields were similar across all cover crop treatments and crop rotation scenarios following the initial year of cover crop implementation at each location. Wheat was planted after cotton harvest. Due to lingering drought conditions under limited irrigation, wheat failed at the Lubbock location and was not harvested. Similar conditions existed at the Vernon locations but grain was planned for harvest. However, a direct hit from an EF-3 tornado decimated the standing wheat crop just prior to harvest and yield was not collected. Crop planted in year 2 of the crop rotation included peanuts, sesame, cotton, and hay after wheat. The hay crop consisted of a cowpea/sorghum-sudan mixture. Severe drought continued to hamper each study sites. At Vernon, crops were planted a little later than normal due to tornado damage. This damage caused delays due to debris cleanup and restoring power to the center pivot irrigation system. All crops at the Vernon site were re-planted due to extreme weed pressure. Cotton, sesame, and peanuts were replanted. However, peanuts used at replanting had a near zero germination rate. Due to timing of the cropping system, mung beans were planted in place of peanuts in late July rather than planting peanuts for a third time that would not allow for a mature peanut crop. Mung beans offer a legume crop option with a short growing season (60-75 days). Hand weeding was conducted at each location for each crop rotation other than the hay crop. Even with hand weeding, another flush of pigweed was observed at Vernon. In total, three post-plant complete tillage operations occurred at the Vernon location for the peanut rotation block, yet pigweed remained prevalent after clean tilling. Weed herbage mass was collected and is currently undergoing data analysis to quantify among treatments. After one season of cover crop implementation and the first phase of crop rotation (cotton), microbial communities and activity, and organic carbon were similar among all treatments. Soil samples were taken shortly after planting phase 2 of the crop rotation in May at each location. These samples were processed and prepped for analysis during the year 2 reporting period. Greenhouse gas fluxes taken during phase 2 crop rotation interval indicated lower CO2 fluxes than the cotton/wheat/hay rotation at the Lubbock location. At Lubbock, continuous cotton treatments had lower stored soil water compared to crop rotation treatments. Crop rotation and diversity has the potential to improve soil function (e.g. increased soil water storage). Cereal rye is a consistent cover crop option in this semi-arid region. Weed pressure and management continues to be a major issue in transitioning organic cotton systems in West Texas. Objective 2: Determine the effects of compost application rate and placement on soil nutrient cycling, greenhouse gas emissions and agronomic and economic viability of organic systems. Due to COVID-19 and subsequent USDA-ARS policies, the project team decided to delay the start of this objective to year 2 of the project. This portion of the project was initiated with the planting of a rye cover crop in fall 2022 at both the Lubbock and Vernon locations. Due to lingering COVID-19 and subsequent USDA-ARS policies, the team decided objective 2 would be continued with simulated or manual subsurface compost applications instead of transporting the original Subsurfer applicator to the Texas locations from Arkansas to apply only on small plots. Thus, rye cover crops were terminated via tillage at each location and cotton was planted. Compost applications were made 3-6 weeks after cotton emergence. Compost treatments included a surface broadcast application rate of 8.96 Mg ha-1. The surface broadcast application was not incorporated as applications were made post-germination. Subsurface applications were made at rates of 4.48 and 8.96 Mg ha-1. Trenches simulating the Subsurfer were manually dug and compost was applied to the trenches and subsequently covered and lightly packed. Greenhouse gas fluxes were monitored throughout the growing season. At Vernon, intense weed pressure and poor stands led to re-planting. All plots were tilled to terminate the existing cotton stand as well as weeds. Cotton was re-planted well past the historical insurable planting date. Hence, measurable yields are not expected at the Vernon location, but bolls will be collected to estimate potential yield and nitrogen uptake in the case the cotton does not fully mature. Objective 3: Disseminate information to students, growers, researchers, county agents, natural resource managers, and regional public officials on the production potential, ecological services, financial viability of evaluated organic cropping systems. The first full crop season cycle was completed in year 2 of the project. These initial findings have been presented at the annual Soil and Water Conservation Society Conference and abstracts were submitted to the ASA-CSSA-SSSA Annual Meeting. Concepts and goals of the project were shared with producers at an organic field day as well as commodity groups. **Publications** - Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: Selph, L., K.L. Lewis, and P.B. DeLaune. 2022.

Crop rotation and cover crop effects on greenhouse gas flux in a transitional organic system. ASA-CSSA-SSSA International Meetings. Baltimore, MD. 6-9 November 2022. - Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2022 Citation: Babcock, R.E., L.E. Selph, K.L. Lewis, and P.B. DeLaune. 2022. Influence of crop rotation and cover crop selection on soil moisture in a transitional organic system. ASA-CSSA-SSSA International Meetings. Baltimore, MD. 6-9 November 2022.

PROGRESS

2020/09 TO 2021/08 Target Audience:As this was the initial year of implementation, little interaction with targeted audiences occurred. However, private organic producers and the Texas Organic Cotton Marketing Cooperative were contacted to disucss project progress and consult about management practices specific to weed management. Changes/Problems: Major problems observed from year 1 were mostly environmental. As mentioned in the accomplishment update, adverse weather conditions in fall 2020 resulted in poor cover crop stand establishment. However, this was easily corrected through replanting of the cover crop. At the TSHP locations, a hail event on June 26, 2021 destroyed to cotton crop (planted May 13). Cotton was replanted on July 7, which is about 2 weeks later than what is typically considered as the cut-off date for ensuring a successful crop. However, a warm fall resulted in a harvestable crop, although yields are expected to be below average. What opportunities for training and professional development has the project provided? During the initial year, graduate students were trained to better understand organic cropping systems and analytical approaches to quantify the impact of cover crops and crop rotation on various soil health indicators. How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals? Plans for the next reporting period to accomplish listed goals include: harvest cotton from year 1, quantify lint yield and quality, plant cover crops and/or rotation crops, complete analysis of samples collected in year 1, continue monitoring soil water storage, collect soil and herbage mass samples for year 2, summarize results from year 1, share results with extension agronomists and economists, disseminate results to producers at regional meetings, and graduate students will begin presenting data at regional and national meetings.

IMPACT

2020/09 TO 2021/08 What was accomplished under these goals? While peanuts are the most widely planted organic rotational crop with cotton, there is a lack of rotational diversity and potential for other rotational crops used in conventional systems that could also meet demands in organic systems. While Texas lags in organic production overall, Texas is the leading producer of organic cotton, peanuts, and rice. Texas grows over 90% of organic cotton and 95% of organic peanuts in the US. We have teamed with the Texas Peanut Producers Board and Texas Organic Cotton Marketing Cooperative to identify agronomic production limitations in respective organic systems. We have also partnered with a sesame company new to the US market, Equinom, to evaluate the potential for sesame as a rotational crop in organic systems. Weed control and soil health management were two main challenges identified in surveys of organic producers, county agents, and industry consultants through direct communication with organic cotton and peanut farmers, which are consistent with the outcomes and recommendations from the 2015 National Organic Farmer Survey and Listening Sessions. In addition, peanut growers have expressed a desire to better understand soil health management (cover crops) but express concerns due to potential stand establishment issues. Based upon this information, our long-term goal is that results from this project will empower organic growers to make informed decisions on inputs that will result in effective weed management, higher and more consistent yields, improved soil health, and carbon (C) sequestration. Research is being conducted in leading organic regions within two varying ecoregions: Vernon in the Texas Rolling Plains of North Texas, and Lubbock in the Southern High Plains. Objective 1: Determine the effects of traditional and non-traditional cover crops and crop rotation on stored soil moisture, soil health, and agronomic and economic viability of organic systems. Studies were initiated in the Texas Southern High Plains at Lamesa (TSHP) and the Texas Rolling Plains at Vernon (TRP) in Fall 2020 with the planting of cover crops. Cereal rye cover crops were planted in November and December at a rate of 16.8, 24.6, and 33.6 kg/ha. Due to freezing rain in the TRP soon after planting, rye was replanted as a result of soil crusting and poor stand establishment. Fennel and fenugreek were drilled into a standing rye cover crop that was planted at 24.6 kg/ha and as a stand-alone mixed cover crop on March 9 in the TRP and March 12 in the TSHP. Record low temperatures were recorded in mid-February across Texas; however, cereal rye proved hardy, and no winter kill was observed. During the first year, cover crop herbage mass, weed herbage mass, soil moisture, and soil chemical, physical and microbial properties were collected. Herbage mass was greatest for rye cover crops at the TSHP location, where herbage mass ranged from 1376 to 1460 kg/ha for the three rye seeding rates. Similar results for rye herbage mass production were observed in the TRP, where herbage mass ranged from about

1340 kg/ha for the 33.6 kg/ha seeding rate to about 1700 kg/ha for the other seeding rates. Planting fennel and fenugreek into standing rye was not successful at either location. As the time of planting corresponded with the beginning of rapid vegetative spring growth of rye, rye appeared to out compete fennel and fenugreek (shading). The fennel/fenugreek mixture was not successful in the TSHP, where only 22 kg/ha of herbage mass was produced. The performance of aromatic cover crops varied by location. In contrast, the fennel/fenugreek mixture produced 1130 kg/ha herbage mass in the TRP. Tillage was used to terminated cover crops at each location. A roller/crimper was used at the TRP location, but tillage was ultimately used to completely terminate the cover crops. Cotton as planted in late May to early June at each location. While little weed pressure was noted at planting due to cover crops and/or tillage, weed pressure rapidly increased soon after planting. Weed herbage mass was collected and is currently undergoing data analysis to quantify among treatments. Initial PLFA data indicated no significant differences after a single year of cover crop implementation. Key outcomes from the initial year, which does not include crop production results, show that herbage mass of rye cover crops did not significantly differ between seeding rates at either location, which supports previous observations. Reduced seeding rates that maintain herbage mass production and subsequent benefits compared to higher seeding rates could provide a significant savings to producers. While weed collection data has not been fully analyzed, the use of aromatic cover crops for improved weed control may not be a viable option in the TSHP or when planted into an established rye cover due to poor establishment. Objective 2: Determine the effects of compost application rate and placement on soil nutrient cycling, greenhouse gas emissions and agronomic and economic viability of organic systems. This objective will be conducted over a two-year period. In addition, this project will also be coordinated with USDA-ARS which has a subsurface applicator for dry manure applications. Due to COVID-19 and subsequent USDA-ARS policies, the project team decided to delay the start of this objective to year 2 of the project. This portion of the project was initiated with the planting of a rye cover crop in fall 2022 at each location. Objective 3: Disseminate information to students, growers, researchers, county agents, natural resource managers, and regional public officials on the production potential, ecological services, financial viability of evaluated organic cropping systems. Data collection have been ongoing since the initiation of this project, which will be key for subsequent analysis and dissemination of results. As we have yet to complete an entire cropping sequence, data have yet to be fully analyzed. As results become available, opportunities for dissemination will rapidly increase. **PUBLICATIONS (not previously reported):** 2020/09 TO 2021/08 No publications reported this period.

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No-till Organic Cropping System for the Dryland Pacific Northwest

Accession No.	1023855
Project No.	WNP02206
Agency	NIFA WN.P\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2020-51106-32484
Proposal No.	2020-02373
Start Date	01 SEP 2020
Term Date	31 AUG 2023
Grant Amount	$499,644
Grant Year	2020
Investigator(s)	Carpenter-Boggs, L.
Performing Institution	WASHINGTON STATE UNIVERSITY, 240 FRENCH ADMINISTRATION BLDG, PULLMAN, WASHINGTON 99164-0001

NON-TECHNICAL SUMMARY

In this project, we will optimize and demonstrate a direct-seeding (no-till) organic cropping system for the Palouse dryland farm. Our goals are to conduct research necessary to optimize the system and document economics, demonstrate the system and conduct outreach, and change producer outlooks on the feasibility of sustainable organic production in this region. The system depends on co-utilization of three recently developed / improved tools. These are a) new highly effective organic registered herbicides; b) sensor-guided selective herbicide application, the WEED-IT; and c) new locally adapted food grade (higher market value) winter pea varieties. These tools are essential and synergistic to provide the needed weed and soil management in a direct seed (no-till) system at an affordable cost. Our objectives are:Determine effectiveness and economics of capric/caprylic acid herbicide, winter peas, and WEED-IT technology as organic weed management tools.Determine interactions of organic herbicides, in field crop systems with and without winter peas, on soil health and insect populations. Determine sensitivity of major regional field crops and weeds to these herbicides. Provide extension and outreach to demonstrate effectiveness and increase interest in a locally adapted organic direct seed cropping system. The project uses a combination of field research, greenhouse research, field demonstrations, and varied outreach and discussion to accomplish the objectives. This project addresses three NOSB research priorities: 1) organic no-till systems, 2) side-by-side trials of organic materials and cultural methods, and 3) production and yield barriers to transitioning to organic production.

OBJECTIVES

We will: Conduct research necessary to optimize an organic cropping system using winter peas, organic herbicides, sensor-assisted spot spraying, and direct seeding for the Palouse dryland farm. Demonstrate and conduct outreach on options and effectiveness of the system and its components (winter peas, organic herbicides, sensor-assisted spot spraying).Document economics of the system and its components. Change producer outlooks on the feasibility of sustainable organic production in this region.

APPROACH

Determine effectiveness and economics of capric/caprylic acid herbicide, winter peas, and WEED-IT technology as organic weed management tools. Field plots will be managed at two certified organic farms, one in Washington and one in Idaho. These plots were planted in winter pea varieties in September 2019 to compare the varieties with differing weed management methods. A second set of plots will be established next to these in 2020. Economic returns will be determined. Data to be collected include: Amounts and costs of herbicides, seeds, equipment, fuel, and/or labor used Biomass, yield, moisture, test weight, protein of peas and following crop pea and weed %N, and d15N to estimate biologically fixed N, crop and weed cover, and weed biomass and species at harvest. Effects on the following crop including weed pressure and soil health effects will be tracked.2. Determine interactions of organic herbicides, in field crop systems with and without winter peas, on soil health and insect populations. This objective is to study important \"secondary\" effects of the main treatments. Insect populations and soil health are significant contributors and indicators of system health. Pea \"weevil\" Bruchus pisorum is a grave concern and may vary among pea varieties. In addition, the active chemicals in the organic herbicides of this study may affect Bruchus or other insects. count and identify weevils and predator insects at 50% flowering of peas. Also quantify % weevil infection in harvested peas, annual soil health by 30 cm to 120 cm including: bulk density, pH, available macronutrients, mineralizable N, dehydrogenase activity, total and active C, water holding capacity. In addition: soil pH at 0-5 and 5-10 cm to test organic acid herbicide effect on field soil pH.3. Determine sensitivity of major regional field crops and weeds to capric/caprylic and d-limonene herbicides. This objective is required because of the new application of capric + caprylic acid in field crops. The relative sensitivity of primary weeds and field crops will determine their best uses, hazards, and crop-specific expenses. And, although this material is composed of fatty acids that biodegrade, its effective herbicidal life on the soil surface is not well understood. In particular in our dry surface soils in late summer to early fall (when winter crops are sown), biological decomposition can be very slow. There is producer concern that residual organic herbicide may burn emerging seedlings. A replicated greenhouse and lab study will test the residual effects and breakdown rate of the organic herbicide, so that producers can be assured of a safe replant time after the final herbicide application. Tests will include: Collect soil from different sites, representing different soil organic C levels and pH. Apply herbicides at a range of dilutions on bare soil and soil with cereal residue cover, at moisture from 5% to 25%.Test different timing of herbicide application vs. seed planting (including applications of herbicide after seeding but before emergence) for plant-back sensitivity of wheat, barley, hemp, canola, peas, lentils, and chickpeas to capric/caprylic acid and limonene herbicides. Apply herbicides at a range of dilutions to growing plants to test sensitivity of multiple varieties of wheat, barley, hemp, canola, peas, lentils, and chickpeas; as well as common weeds at different life stages and height/size to determine effective concentrations to use in field depending on weed population .Additional test with thistles, which often become too tall to spray: cut plant at soil level, then spray base to test effectiveness of a mow + spray weed management technique vs. only cutting vs. only spraying. Spray both weed species and crop species at the soil level to test durability to girdling by herbicides and their compatibility with herbicide use between rows.4. Provide extension and outreach to demonstrate effectiveness and increase interest in a locally adapted organic direct seed cropping system, including organic herbicides and winter peas for managing weeds .Outreach of project will includeAnnual field days at multiple sitesPresentations and webinars to grower associationsarticles in grower magazinesExtension bulletinevaluations of grower responseMilestones:Prior to funding, 2019-2020:Establish plot areas at 2 certified organic farms Manage and monitor weeds Monitor pea weevil and predators Year 1, 2020-2021: Greenhouse sensitivity studies Manage and monitor weeds Monitor pea weevil and predators Harvest plots, analyze crop yield, quality Take soil samples and conduct analyses Field day presentations, demonstrations Year 2, 2021-2022:Greenhouse sensitivity studies Manage and monitor weeds Monitor pea weevil and predatorsHarvest plots, analyze crop yield, quality Take soil samples and conduct analyses Write manuscriptField day presentations, demonstrations Grower organization presentations and/or webinars Year 3, 2022-2023:Field day presentations, demonstrations Harvest plots, analyze crop yield, quality Take soil samples and conduct analyses Submit manuscript Grower organization presentations and/or webinarsGrower magazine submissionPrepare Extension article Progress 09/01/21 to 08/31/22 Outputs Target Audience:The primary audience for this project are dryland agricultural producers in the Pacific Northwest USA (PNW) who are considering transition to organic. The research and demonstrations are conducted in the PNW, and so the findings and agricultural timings will be most relevant here. Field crop producers in irrigated areas may also adopt the system or components. Through outreach, the information will also become available to researchers and growers regionally and nationally. Depending on climate and agricultural system, one or more components or the 3-part system will be relevant in much of the USA and beyond, although the varieties, timings, and other details will differ. Current dryland certified organic producers in the PNW (which are few) were targeted as cooperators and audience. In the first field season, one certified organic producer and one that has had certified acreage in the past were our cooperators. More growers are considering transitioning to organic production. These growers are widely distributed, but tend to belong to the Tilth Producers Alliance or Pacific Northwest Direct Seed Association. Therefore outreachspecifically includedthese organizations. Changes/Problems:Although not previously planned, we will undertake a 3rd year of field trials using the same plot design. Given the first 2 years of the study both met with extreme weather conditions, we are hopeful that a 3rd year will provide more meaningful data. What opportunities for training and professional development has the project provided?Graduate student attendedASA, CSA, SSSA International Annual Meeting inSalt Lake City, UT. November 2021. He presented a poster about the research.Appleby, A.B. and L. Carpenter-Boggs (2021). Efficacy and Economic Viability of Organic Herbicides. Two undergraduate students were employed and trained to assist in soil sampling, soilnitrogen extraction, plot harvest, pea cleaning, and protein analysis. How have the results been disseminated to communities of interest?We conducted 2 workshops: Workshop at Tilth Alliance 2021 Conference. Organic Herbicides: Fitting into an Integrated Weed Management Plan Presentation for Palouse Conservation District. Soil Health Sit Down: Organic Herbicides and Their Potential Role in Palouse Agriculture. Dec. 16, 2021. https://www.youtube.com/watch?v=aji3DWrqgaY What do you plan to do during the next reporting period to accomplish the goals?Although not previously planned, we will undertake a 3rd year of field trials using the same plot design. Given the first 2 years of the study both met with extreme weather conditions, we are hopeful that a 3rd year will provide more meaningful data. Greenhouse trials will commence in earnest using the fresh materials obtained. Analyses of soils, crop samples, and weed biomass will continue. Impacts What was accomplished under these goals? This project aims to improve weed management in dryland organic agriculture using a two-pronged approach. The first strategy involves introducing a more competitive, food-grade winter pea variety to suppress weed growth through crop competition. The second strategy employs targeted applications of organically approved, plant-based herbicides to enhance weed control while minimizing input costs. We are also assessing the impact of these interventions on soil fertility, particularly changes in mineralizable nitrogen (N) contributed by the peas. The organic herbicides tested in this study includeAvenger (active ingredient: d-limonene) andSuppress (active ingredients: capric and caprylic acids) Year 2 Activities: In the second year, we conducted field trials at two locations: Lewiston, Idaho and Pullman, Washington. The experimental design followed a randomized complete block design (RCBD) with split plots. Treatments included two organic herbicides, a mechanical weed control treatment, and a no-weed-management control, tested across four different pea varieties. The 2022 growing season presented highly unusual conditions. July alone brought 4.2 inches of precipitation\--well above the norm\--which resulted in exceptionally vigorous crop and weed growth. Unfortunately, this excessive moisture rendered all weed control methods ineffective beyond the initial few weeks of the season. As a result, none of the strategies tested were able to maintain effective weed suppression for the full growing season. Soil Analysis: Soil samples were collected at both sites before and after the field season, and are currently undergoing laboratory analysis to assess available N, mineralizable N, and pH. These data will help us determine the soil fertility impacts of winter peas and how they interact with the different weed management strategies. Greenhouse Trials: Greenhouse trials of the herbicides were always planned but have become a much more important part of the study due to 2 years so far of terrible weather (drought in 2021 and monsoon in 2022). Fresh and viable seeds were collected for numerous important weeds of the area includingItalian Ryegrass, Rattail Fescue, Wild Oat, Mayweed Chamomile, Redroot Pigweed, and Canada Thistle (rhizomes). Publications **Progress** 09/01/20 to 08/31/21 **Outputs** Target Audience:The target audience for this project includeproducers, researchers, students, and agricultural professionals. The audience may come from several different interests including pea production, dryland agriculture, organic agriculture, sustainable agriculture, weed management, natural bioproducts, agricultural economics, or sustainable agriculture. Producers currently in low-rainfall dryland agriculture are the most likely to use information developed in this project. Agricultural professionals such as extension agents, crop advisors, and regulators are the next likely tier who will use the information and disseminate findings to producers and other members of the industry. Students who may become engaged in organic or sustainable production will be interested to learn about economically viable products and methods to reduce both weed pressure and erosion. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest? Nothing Reported What do you plan to do during the next reporting period to accomplish the goals?Presentations are planned for Tilth Alliance conference, November 2021 (Washington State's largest organization for organic and sustainable producers); Palouse Conservation District, December 2021. **Impacts** What was accomplished under these goals? Research was initiated at two collaborating farms, one of which is organic certified but not direct-seed and one is direct-seed but not organic. Four pea varieties were direct-seed planted at both sites, and managed with four approaches to weeds: no management (negative control), mechanical management (cultivating wheel hoe), d-limonene based organic registered herbicide, and capric + caprilyc acid-based organic registered herbicide. Optimization is proceeding through observations and data collection of weed and crop responses. The 2021 cropping season was a historic drought in our region, leading to extremely low crop yields. Research plots at both sites were not suitable for field demonstrations. Data are being collected such as amount of chemical applied per unit area, number of applications, and hours of labor, that are needed to determine the economics of our treatments. In addition, collaborating farms have agreed to allow our observation and collection of data to determine the economics of their current weed control methods and their use of organic registered herbicides. Because of the high expense of the herbicides, growers will use the herbicides in additional ways and specific conditions where they see the most value. Documenting the effects and costs of these uses will add to the knowledge base for organic producers. **Publications**

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